The role of uncertainties of modelled soil carbon in an inventory-based carbon budget of Finnish forests

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Abstract

The uncertainty of regional carbon budgets of forests is currently an issue of special interest due to requirements set for the greenhouse-gas reporting. In this work, we analysed the uncertainty of carbon budget calculation of Finnish forests. The calculation combines inventory data, biomass expansion factors, turnover rates and a dynamic soil carbon model.

In order to make assessments about the role of vegetation and soil in forest carbon models, one should also take into account the uncertainties in models. In this study, first, we tested the aggregate effect of uncertainties in input data and vegetation on the uncertainties of soil carbon sink and stock. Secondly, we tested how much the uncertainties of soil model parameters add up to the uncertainty of soil carbon sink and stock.

According to the results, the soil model parameters dominated the uncertainty of forest carbon estimates, especially that of the soil carbon stock. The improvement of precision of vegetation parameters and input data do not necessarily improve the estimates of soil.

Introduction

The studies concerning the uncertainties of forest carbon budgets are few although there is a strong political stress for the estimates of uncertainties (UNFCCC, 1997, 2001). So far, there are few studies, which take into account both vegetation and soil in forest carbon assessments. Existing studies have more or less focused on the sensitivities of the system or uncertainties of forest carbon scenarios (Kurz and Apps, 1994; Chen *et al.*, 2000; Heath and Smith, 2000; Zhang and Xu, 2003), There is a need for studies, which consider the reporting perspective of forest carbon.

The objective of this study was to assess the role of soil in a national level forest carbon budget, taking into account the uncertainties within the calculation.

Materials and methods

The forest carbon model combines aggregated forest inventory data, growth variation of trees, statistic on removals (hereafter called input data), and models of biomass and its turnover (vegetation parameters), and a dynamic soil carbon model, Yasso (Liski *et al.*, 2005). The calculation of forest carbon budget of Finnish forests (upland soils) was performed for years 1988-2002; in this study the results are presented for year 1993.

The biomass of trees is calculated from inventory estimates of growing stock using biomass expansion factors (Lehtonen *et al.*, 2004) Ground vegetation biomass is calculated using forest area estimates and mean biomass (Peltoniemi *et al.*, 2004). These two sum up to vegetation biomass, of which 50 ± 1% (SD) is carbon.

In order to operate, the soil model requires data on annual litter input, and climatic variables (temperature sum, drought = PET-precipitation). The litter input is derived from biomass estimates using turnover rates. The soil model starts from a steady state with the input and climate of the first year. The time step for the system is one year, and the sinks are calculated as differences between two consecutive stocks.

All of the input data and all parameters of forest carbon model were appended with uncertainty estimates (Monni *et al.*, manuscript in revision; Peltoniemi *et al.*, manuscript in preparation). Due to the lack of data, the estimates of variable distributions were often based on expert opinion.

For the analysis of this study, we did a Monte Carlo type of simulation. Random samples were taken from variable distributions, and the calculations were repeated several thousand times. After 6 000 simulations, the variance of result variables stabilised within 1%, and the simulations were stopped, and the results were analysed.

The role of vegetation uncertainties in the vegetation and soil carbon stock and sink uncertainties were tested by increasing the distribution widths of vegetation parameters and input data. The roles of uncertainties of soil model parameters, and the roles of input data and vegetation parameters, were compared by decreasing the uncertainties related to soil models parameters. This way, the effect of uncertainty in the quantities of litter was reflected to dynamic system of soil.

Results and discussion

The vegetation carbon sink was very sensitive to assumptions of uncertainties unlike the soil carbon sink (Figure 1). This is due to the fact that soil carbon sink was also contributed by uncertainties related decomposition and climatic conditions affecting it. Stocks of carbon were less affected by the increases of uncertainties. This is understandable because there are more parameters that contribute to the uncertainty of stocks; sinks are calculated here as a difference between the stocks and the effect of most parameters cancels out.

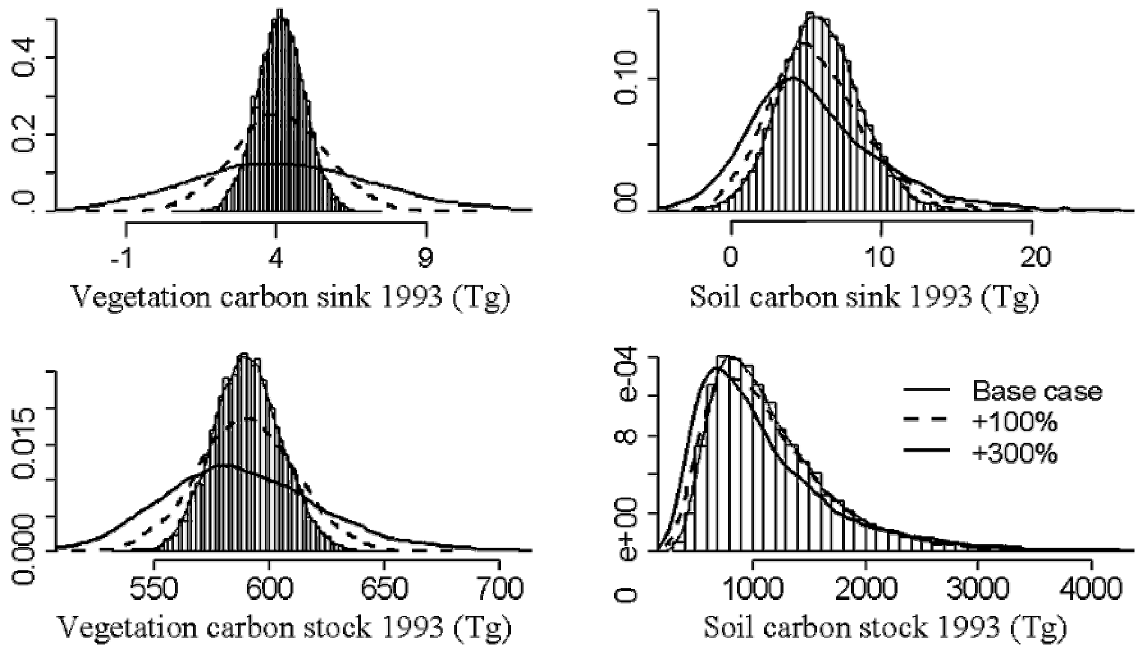

Figure 1 Effect of increases in uncertainties of input and vegetation parameters on vegetation and soil sink and stock.

The role of soil model parameters was notable in the uncertainty of soil carbon stock (Figure 2). Their effect on soil sink was somewhat smaller. The sink estimates are mainly driven by changes of input; the soil model parameters do not contribute as much to the estimates of sinks as estimates of stocks. Therefore, the uncertainty of sinks did not decrease as much as the uncertainty of stocks when the soil model parameters were assumed precise. An interesting side product of this exercise is the limit for the precision of soil sink or stock with this model construction, which assumes exponential decay for soil carbon.

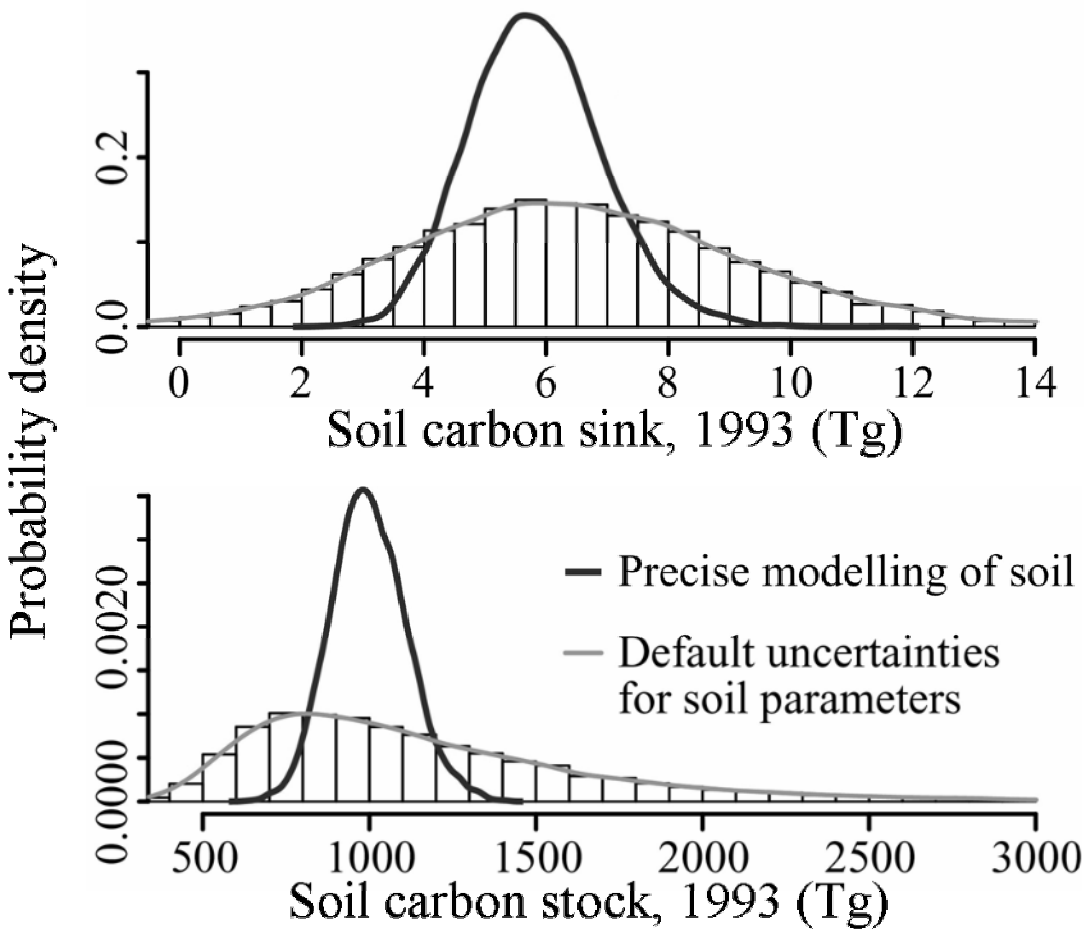

Figure 2 The uncertainty of soil carbon sink and stock when soil model parameters did not include any uncertainty in comparison to the simulation with default uncertainty estimates for soil model parameters.

These kinds of studies are sensitive to the assumptions of uncertainties for initial parameters and, therefore, involve subjectivity. However, a non-subjective analysis that would assume some fixed percentage error for all variables is more likely to give unreasonable results. In this study, we concentrated on the aggregate effect of all vegetation parameters and input data and, on the other hand, on aggregated effect of all soil model parameters. It is unlikely, that we would have failed in estimating all uncertainties for all parameters within these groups. Furthermore, this study did not aim at giving confidence levels for the estimates but to compare the role of these two large carbon pools.

Conclusions

The large uncertainty in the results of soil carbon stock and sink, and the small role of vegetation in these uncertainties, implies that more work should be focused into the improvement of methods to model soil on a national level. With the approach of this study, the more precise estimates of vegetation parameters and input data do not improve the estimates of soil.

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