Modelling past and future impacts of changes in climate, nitrogen deposition, ozone and CO_2 exposure on carbon sequestration in European forests

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Overview

Carbon sequestration in forests and forest soils is influenced by various drivers including changes in climate (temperature and water availability), nutrient (nitrogen, base cations, phosphorous) availability, carbon dioxide (CO_2) exposure and ozone (O_3) exposure. We modelled the effects of those drivers on tree and soil carbon sequestration of European forest for the period 1900–2050, by using and combining the forest growth model EFISCEN with the soil model VSD+. Impacts of drivers on forest growth were assessed by modifying a reference growth with factors accounting for each driver, using various assumptions with respect to interactions. The forest growth model was coupled to a soil model predicting nutrient availability and soil carbon sequestration. The study shows amongst others that N deposition was a dominant driver of changes in forest growth in the past (1900–2010), whereas climate change is estimated to be the dominant driver of forest growth in the future (2010 - 2050).

Methods/Approach

We modelled the combined effects of past and expected future changes in climate, nitrogen deposition, ozone and CO_2 exposure on carbon sequestration in European forests for the period 1900–2050 following an approach described in De Vries and Posch (2011). Forest inventory data around 1980 were used to assess reference forest growth rates, which were then modified for other years by factors accounting for deviations in climate and air quality compared to 1980. The impacts were evaluated using various assumptions with respect to interactions between drivers. Impacts of soil macro-nutrient availability (P, Ca, Mg, K) were also accounted for.

Historical meteorological data were taken from a high resolution European data base that contains monthly values of temperature, precipitation and cloudiness for the years 1901–2000. Oxidised and reduced N deposition was calculated with the EMEP model. In addition, the phytotoxic ozone dose (POD) was calculated by the EMEP model, incorporating the DO3SE deposition module, which parameterises ozone uptake as functions of phenology, light, temperature, humidity, and soil moisture (Simpson et al., 2003). Historic NO_x, NH_3 and VOC emissions were taken from Lamarque et al. (2010). For the future (2010-2050) we used two scenarios for deposition (current legislation and maximum technically feasible reductions) and two climate scenarios (no change and SRES A1 scenario).

Results

An evaluation of the individual effects of N deposition change, assuming the CLE scenario, and climate change, assuming the A1 scenario, in the period 1900–2050 is presented in Fig. 1. The assessments were made neglecting the effect of CO_2 and O_3 exposure and other nutrient (P and base cation) limitations. The results show that N deposition has been the major cause for changes of C sequestration in the past, while climate change is the major cause for future increases in C sequestration, off-setting the effect of reduced N deposition. The effect of N deposition was evaluated using two different relationships between N deposition and growth, i.e. a trapezoidal and a linear response function appears to be large for these runs with no nutrient limitations. Since N deposition changes are occurring mainly in the low N deposition range, much larger C sequestration effects were simulated for the response function approximated by the trapezoidal shape than for the linear response function (compare Fig. 1a and 1b). Base cation limitations, specifically Mg limitation, may significantly affect predicted growth in the future, as it will become more limiting with an increased growth of forests. The fertilizing effect of CO_2 is most likely reduced by N limitation. Furthermore, changes in ozone exposure have affected foreste growth in the past and will do so in the future.

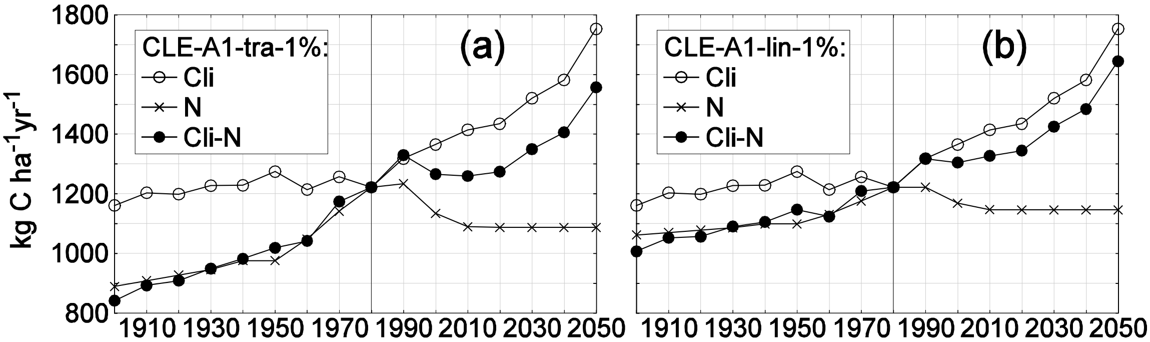

Fig. 1. Past and future development of the mean annual European tree C sequestered as a function of N deposition only, climate change only, and both N deposition and climate change: (a) using the reference Ndep-growth relationship (‘tra-1%’) and (b) the linear (‘lin’) function with a 1% increase, all under the CLE deposition and A1 climate change scenario.

References

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