Constraining Estimates of Carbon Sequestration under elevated CO_2 by Combining Carbon Isotope Labelling with Soil Carbon Cycle Modelling.

Niklaus, P. A. (1,2), & Falloon, P. (3)
(1) Institute of Plant Sciences, ETH Zurich, Switzerland
(2) Institute of Botany, University of Basel, Switzerland
(3) Met Office, Hadley Centre for Climate Prediction and Research, Exeter, Devon

Plant growth is often stimulated by elevated atmospheric CO_2 concentrations, but herbaceous plants have only a relatively limited capacity to store extra carbon (C). However, net ecosystem production could increase more than plant biomass because C could be transfered to and stored in soils, constituting a negative feedback on the atmospheric CO_2 rise.

We exposed nutrient-poor calcareous grassland for six years to elevated CO_2 (600 ppmv). The commercial CO_2 applied had a distinct $\delta^{13}C$ so that the incorporation of elevated CO_2-C (C_{new}) into soils could be followed. Here, we explore how estimates of C sequestration under elevated CO_2 can be constrained by combining this ^{13}C labelling with soil C modelling using the Rothamsted carbon cycling model (*RothC*).

Inverse modelling predicted a total input of C_{new} of 1240±2 g C m^{-2} over the March 1994 to June 1999 treatment period. The model reproduced the measured dynamics of very well and data were in good accordance with biomass-based estimates of NPP. By the end of the study, the largest fraction of C_{new} was stored as resistant plant material, but a significant amount of new humified material had also built up.

The estimates of C sequestration could be constrained in several steps: (1) The net incorporation of C_{new} into soil organic matter in elevated CO_2 plots indicated an upper limit of C sequestration of ≈90 g C m^{-2} yr^{-1}. (2) Using *RothC*, the decomposition of 365 g C m^{-2} yr^{-1} pre-experimental C (C_{old}) was calculated for the same period, reducing net sequestation estimates to 34 g C m^{-2} yr^{-1}. The modelled decomposition of C_{old} was relatively constant with time, whereas C_{new} inputs were larger in the first years – calculated net sequestration rates therefore levelled off after ≈2 years. (3) Ambient CO_2 plots are unlikely to be C neutral; C sequestration in elevated CO_2 plots therefore does not correspond to elevated CO_2-induced C accretion. The soil C balance of ambient CO_2 plots is difficult to estimate in the absence of isotopic tracer – assuming soil C inputs proportional to aboveground NPP yielded a difference in C balance of ≈15 g C m^{-2} yr^{-1} between CO_2 treatments. (4) Soil moisture was higher in elevated CO_2 plots due to reduced leaf conductance and evapotranspiratory water losses. Simulating the reduced evaporative demand of vegetation under elevated CO_2 and associated alleviation of decomposition resulted in an extra loss of 19 g C_{old} under elevated CO_2.

In conclusion, extra C was only detected in rapidly turning-over fractions such as plant biomass and detritus and the combination of C isotope measurements with modelling suggests that elevated CO_2-induced soil C sequestration may be rather limited or not occurs at all. This is consistent with the observation that soil C fluxes are predominantly determined by the faster-cycling fractions whereas total soil organic C pools are dominated by the slowly turning-over pools.