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

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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 C_{new} 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 decomposi-

tion 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.