A model for three-way carbon flux partitioning in calcareous soils using stable isotope measurements

Guy Kirk 1, Chris McCloskey 1,2, Wilfred Otten 1, and Eric Paterson 2

1 Cranfield University, School of Water, Energy, and the Environment, Cranfield, Bedfordshire, United Kingdom
2 The James Hutton Institute, Craigiebuckler, Aberdeen, Scotland, United Kingdom

In order to understand and model soil carbon (C) dynamics it is essential that we are able to partition net ecosystem C exchange by individual organic and inorganic fluxes under field conditions. Stable isotope methods provide a reliable means to separate fluxes from two sources, such as plant respiration and soil organic matter (SOM) mineralisation. In many soils, however, plant and soil respiration are not the only sources of C efflux, as breakdown of carbonate minerals provide a third, inorganic, C source. We currently lack methods and models to allow us to untangle plant, inorganic soil, and organic soil C fluxes in the field. This limits our ability to gather field-scale plant and soil C flux data to soils without inorganic carbonates, rendering calcareous soils a major gap in our understanding of, and ability to model, soil C dynamics.

To remedy this we have developed a novel three-way partitioning model to account for inorganic carbonate dissolution in a planted soil. Analysis of a mechanistic model of lime (CaCO₃) dissolution showed differences in CO₂ pressure in the soil, arising from differences in soil respiration as influenced by differences in temperature and moisture, to be a major control on dissolution rates. The three-way partitioning model we have developed derives the CO₂ flux from CaCO₃ dissolution from SOM mineralisation and below-ground plant respiration fluxes.

To test this model we used cavity ring-down spectroscopy to measure CO₂ fluxes from soil mesocosms containing C3-origin SOM and planted with a C4 grass, both with and without CaCO₃, and unplanted soil mesocosms containing CaCO₃. As previously field measurements revealed temperature to be the strongest control on soil respiration this was carried out at four temperatures (15, 20, 25, and 30°C). Using the distinct δ¹³C values for CaCO₃ dissolution, C4 grass respiration, and C3 SOM mineralisation, fluxes were partitioned from mesocosms containing two C fluxes to parameterise the model. The model was tested through application to flux data from mesocosms containing C fluxes from CaCO₃, SOM, and plants in order to assess its suitability for generating novel field datasets of C fluxes from calcareous soils.