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Empirical modelling of plant and soil carbon flux drivers under field conditions

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Our understanding of soil carbon (C) dynamics is limited; field measurements necessarily conflate fluxes from plant and soil sources and we therefore lack long-term field-scale data on soil C fluxes to use to test and improve soil C models. Furthermore, it is often unclear whether findings from lab-based studies, such as the presence of rhizosphere priming, apply to soil systems in the field. It is particularly important that we are able to understand the roles of soil temperature and moisture, and plant C inputs, as drivers of soil C dynamics in order to predict how changing climate and plant productivity may affect the net C balance of soils. We have developed a field laboratory with which to generate much-needed long-term C flux data under field conditions, giving near-continuous measurements of plant and soil C fluxes and their drivers.

The laboratory contains 24 0.8-m diameter, 1-m deep, naturally-structured soil monoliths of two contrasting C3 soils (a clay-loam and a sandy soil) in lysimeters. These are sown with a C4 grass (*Bouteloua dactyloides*), providing a large difference in C isotope signature between C4 plant respiration and C3-origin soil organic matter (SOM) decomposition, which enables clear partitioning of the net C flux. This species is used as a pasture grass in the United States, and regular trimming through the growing season simulates low-intensity grazing. The soil monoliths are fitted with gas flux chambers and connected via an automated sampling loop to a cavity ring-down spectrometer, which measures the concentration and ¹²C:¹³C isotopic ratio of CO₂ during flux chamber closure. Depth-resolved measurements of soil temperature and moisture in each monolith are made near-continuously, along with measurements of incoming solar radiation, rainfall, and air temperature at the field site. The gas flux chambers are fitted with removable reflective backout covers allowing flux measurements both incorporating, and in the absence of, photosynthesis.

We have collected net ecosystem respiration data, measurements of photosynthesis, and recorded potential drivers of respiration over two growing seasons through 2018 and 2019. Through partitioning fluxes between plant respiration and SOM mineralisation we have revealed clear diurnal trends in both plant and soil C fluxes, along with overarching seasonal trends which modify both the magnitude of fluxes and their diurnal patterns. Rates of photosynthesis have been interpolated between measurement periods using machine learning to generate a predictive

model, which has allowed us to investigate the effect of plant productivity on SOM mineralisation and assess whether rhizosphere priming can be detected in our system. Through regression analyses and linear mixed effects modelling we have evaluated the roles of soil temperature, soil moisture, and soil N content as drivers of variation in plant and soil respiration in our two contrasting soils. This has shown soil temperature to be the most important control on SOM mineralisation, with soil moisture content playing only a minor role. We have also used our empirical models to suggest how the carbon balance of pasture and grassland soils may respond to warming temperatures.