Title: Belowground Allocation and Dynamics of Recently-Fixed Plant Carbon in a California Annual Grassland Soil

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Project Goals: The overarching goal of our project is to understand how cross-kingdom and within-kingdom interactions (involving viruses, bacteria, archaea, fungi, protists, microfauna, and plant roots) provide a functional foundation for nutrient cycling in grassland soils. We are using stable isotopes, solid state ^{13}C-NMR spectroscopy, density gradient-based separation, and ecosystem modeling to unravel how biotic interactions shape the flow and fate of C and N in soil. The primary goals of the work discussed here are to: 1) follow the temporal and spatial dynamics of recently fixed plant C and 2) explore the incorporation of plant-derived carbon into the soil organic carbon stock in soil.

The flow and fate of plant fixed carbon (C) was followed for two years after a five-day $^{13}CO_2$ field labeling of a Northern California annual grassland. Soil and plant samples were collected immediately after the labeling pulse, and again at three days, three weeks, six months, one year, and two years. Soil organic matter was fractionated using a sodium polytungstate density gradient to separate the free-light fraction (FLF), occluded-light fraction (OLF), and heavy fraction (HF). Using isotope ratio mass spectrometry, ^{13}C enrichment and total C content was determined for plant shoots, roots, soil, soil dissolved organic carbon (DOC), and the FLF, OLF, and HF fractions. The HF fraction was analyzed by solid state ^{13}C NMR spectroscopy.

At the end of the labeling period, the largest amount of ^{13}C was recovered in plant shoots, but a substantial amount was also found belowground in roots, soil, and soil DOC. Density fractionation of 3-week soil samples (from which living roots were removed) indicated that the highest isotope enrichment occurred in the mineral-rich heavy fraction. After 6 months, when plant shoots and roots had died during the dry summer period, the amount of label in the FLF was equal to that in the HF. By the 1-year sampling, ^{13}C in the FLF had declined substantially and by the end of the 2-year period, 69% of label was in HF, 18% in FLF and 13% in OLF.

While the total ^{13}C content of the HF did not change measurably from the 3-week sample to the 2-year sample, ^{13}C NMR spectroscopic analysis of spring HF samples from 2018, 2019, and 2020 suggests that the relative proportion of aliphatic/alkyl functional groups declined over the 2-year period. Simultaneously, aromatic and carbonyl functional groups increased and the proportion of carbohydrate groups remained relatively constant.

In summary, plant photosynthate C appeared in soil rapidly after being fixed, and by 3 weeks, a substantial amount of the total plant-derived ^{13}C had become associated with the heavy

Fraction (HF) of soil. While the amount of ^{13}C associated with this fraction did not then change measurably over the following 2 years, functional group characterization by ^{13}C NMR spectroscopy showed changing chemical characteristics of the mineral associated organic matter, including declines in aliphatic/alkyls and increases in aromatic and carbonyl functional groups.

References/Publications:

Fossum, Christina, et al. (2020). *Allocation and dynamics of recently fixed plant carbon in a California rangeland soil* (Master's thesis, University of California, Berkeley).

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