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Belowground allocation and dynamics of recently fixed plant carbon and soil organic matter in a California annual grassland

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Plant roots and surrounding organisms are a primary source for stabilized soil organic carbon (SOC), yet few field-based studies have directly quantified the amount of plant-fixed C that moves into soil and persists over multiple years. We tracked the fate of plant-fixed C following a five-day 13CO2 labeling of a California annual grassland, measuring C pools immediately after labeling and at 3 days, 4 weeks, 6 months, 1 year and 2 years. SOC was density fractionated to separate the free-light fraction (FLF), occluded-light fraction (OLF), and heavy fraction (HF). We then measured 13C enrichment and total C content for plant shoots, roots, soil, soil dissolved organic carbon (DOC), and the FLF, OLF, and HF. We used solid state 13 C NMR to resolve the chemical nature of HF-SOC.

Right after the 13C labeling, 40% of the 13C was already belowground, in roots, soil, and soil DOC. By 4 weeks, the highest isotope enrichment and 27% of the remaining 13C was associated with the HF. After 6months and the summer drought, the FLF and HF were similarly enriched. Thereafter, the FLF enrichment declined over the following 2 years. By the end of the 2-year experiment, 67% of remaining label was in the HF, 19% in the FLF, and 14% in the OLF. While the HF 13C content was stable over the final year, the chemical forms of HF SOM changed with time. Aliphatic/alkyl C functional groups declined in the newly formed SOC over the 2 years in the field, while aromatic and carbonyl/carboxylic C functional groups increased and the proportion of carbohydrate (O-alkyl C) groups remained relatively constant.

Our results indicate that plant-fixed C moved rapidly into soil and became mineral associated within weeks. While most of the annual plant C input in these grasslands cycles rapidly (<2- year timescale), a sizeable proportion (23% of the initial pulse of plant-added 13C) persisted in the soil for longer than 2 years. This study revealed surprisingly rapid movement of plant C into the HF of soil, followed by subsequent evolution of the chemical forms of organic C in the HF.