F. RESEARCH

F.1 Research statement

Earth system models vary widely in their predictions of carbon (C) uptake and release by the biosphere, partly due to great uncertainties in the response of soils, one of the largest C reservoirs in the surface earth system. The world's soils play a major role in the exchange of greenhouse gases with the atmosphere, in sustaining primary production, and in providing food security. Despite this, the sensitivity of soils to current and historic changes in climate and land use remains highly uncertain. My research draws from biogeochemistry, ecology, soil science, and biogeography to advance our knowledge of environmental and anthropogenic factors regulating terrestrial C storage. My questions cross spatial and temporal scales – from microscopic to regional and annual to millennial. My approach encompasses conceptual, synthetic and experimental research, fieldwork, and laboratory measurements. Below I highlight selected contributions under three themes. I use the plural we to indicate work with my students.

Hierarchical controls on carbon turnover within and across ecosystem boundaries
Improving estimates of feedbacks between the biosphere and the climate system requires enhanced understanding of mechanistic controls on C turnover. My research applies multiple approaches, including isotopic and spectroscopic data, to measure molecular and environmental factors regulating biogeochemical processes to inform predictions of future change.

The residence time and retention of C in soils is strongly influenced by soil properties, e.g., mineralogy and structure, which are not well represented in biogeochemical models coupled to land and climate models. Most knowledge of soil C comes from temperate regions, despite the major role of tropical soils in the global C cycle. Even in the tropics, available data are not representative [1] and our research shows mechanisms differ in highly weathered soils [e.g., 2]. With NSF CAREER funding, I am investigating hierarchical controls on C turnover in a diversity of tropical soils to improve understanding of C dynamics. This work will produce one of the largest databases for tropical radiocarbon data to better constrain estimates of soil C age.

Soils are the dominant contributors of C to inland and coastal water bodies, influencing aquatic productivity and greenhouse gas production. Despite this, terrestrial and aquatic research communities often work in isolation of each other. I led an interdisciplinary effort to reveal how emerging conceptual models in soil organic matter (OM) research can resolve long-standing paradoxes surrounding the fate of land-derived C in marine systems [3]. We proposed that predictions of the reactivity of OM should be reassessed given: 1) a shift away from an emphasis on chemical recalcitrance as a primary predictor of turnover, 2) new interpretations of radiocarbon ages, 3) and the recognition that most dissolved OM leaving soils has been microbially processed. Drawing from this work and my research on the hydrologic transport of C in soils [4], I plan to investigate terrestrial-aquatic C fluxes with the North Temperate Lakes Long-Term Ecological Research (NTL-LTER) group.

Legacies of past climate and landscape disturbances on terrestrial carbon storage
Improved mechanistic understanding of OM storage during past periods of environmental change can help predict the vulnerability of terrestrial C to current and future trends. My research

has focused on the response of soil C to climatic and anthropogenic transformations of the landscape.

In a novel approach that combined biogeochemistry with geomorphology, we found that landscape disturbance during a period of rapid climatic change contributed to the persistence of ancient C in a deeply buried paleosol [5]. This research, which was published in *Nature Geoscience* and received international press coverage, revealed that buried soils are a grossly underestimated reservoir of C that could become a C source if reconnected to the atmosphere through erosion or other disturbances. In a new synthesis of existing data on buried soil C globally, we proposed that depositional processes play an underappreciated role in the accumulation and storage of organic C at depth [6], contributing a new perspective on the source of deep soil C. Future work will examine the vulnerability of buried C to environmental change to assess the potential risk of C release to the atmosphere.

Pedogenic factors can influence the sensitivity of soils to disturbance. In one of the few studies of land use effects on landscape-scale variability in arid soils, we found differences in soil C and nitrogen across different parent materials within the same soil order [7]. This work highlights the importance of assessing interactions between geologic and human factors in regional C inventories and of identifying mechanisms influencing the response of soils to land use.

With funding from the USDA and my NSF CAREER award, I have initiated research to quantify soil C under different land cover types. This project is part of a national effort to improve baseline data for climate and land use projections and better understand the effects of historical land use on current C stocks. Despite the known importance of former land-use legacies on soil C cycling, most regional and global soil C mapping efforts lack any consideration of site history.

Interactions between biodiversity and biogeochemistry in human-dominated ecosystems
Human modifications of the landscape alter species composition, with consequences for biogeochemical cycling and conservation. My research addresses interactions between changing plant and microbial diversity and ecosystem processes through experimental manipulations and historical changes in land cover.

The transformation of agriculture for bioenergy crop production has implications for the environmental sustainability of biofuels. In a collaborative project funded by the USDA, we found positive relationships among plant diversity, microbial communities, and soil C accumulation [8]. With support from the Great Lakes Bioenergy Research Center and the Radiocarbon Collaborative, we are examining how crop type affects soil OM pools and the age of microbially-respired C across soils of contrasting texture. This work contributes to theory on how diversity affects ecosystem function and to evaluating the full effects of land use conversion for bioenergy.

Human use can launch sites on new trajectories, with unpredictable consequences for above- and belowground ecological interactions and the provision of ecosystem services. Our NSF-funded research has found strong plant-driven successional controls on microbial ecology in post-agricultural forests [2, 9]. Changes in plant communities influence soil nitrogen and biomass C accumulation [10, 11], affecting ecosystem C sequestration potential. Building upon my work on reforestation effects on soil C [1, 12, 13], ongoing research in my lab will close some of the gaps in knowledge of how land-use legacies alter forest recovery in Earth system models.

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