Research Statement
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Land use and land cover changes have the potential to alter ecosystem structure and function through direct and indirect effects on species composition and on biogeochemical cycling. Multiple cycles of human disturbance are leading to the formation of novel species assemblages, with unknown effects on ecological interactions and the long-term ability of these new communities to provide important ecosystem services. Changes in land use and land cover are also affecting the timing and magnitude of water, carbon, and nutrient fluxes within and across ecosystems. Disturbed ecosystems may be more susceptible to future changes in climate, and become greater sources, rather than sinks, of carbon and nitrogen to the atmosphere and waterways. My approach to studying these and other environmental challenges is to link ecosystem processes across the soil boundary.

My research is driven by a desire to understand how ecosystems respond to global change in order to improve our management of natural resources and for the rehabilitation of degraded lands. I am trained as an ecosystem ecologist and biogeochemist interested in the biogeographic aspects of land use and land cover change. My background and interests are interdisciplinary and I enjoy collaborating across the natural and social sciences. My research integrates field and laboratory experimental work to understand the effects of human disturbance on species composition, as well as factors controlling the stabilization and losses of organic matter and elements. I use ecological methods, stable and radioisotopes, and spectroscopic techniques to quantify process rates, identify sources and sinks, and better understand underlying mechanisms controlling ecosystem processes and biogeochemical cycling. My work crosses different scales, from landscape-level secondary forest stand dynamics to microscopic interactions between organic matter and mineral surfaces in soils.

Future research directions

I am interested in how landscape transformations by human activities affect biodiversity and the cycling of elements and nutrients through soils, the biosphere, atmosphere, and hydrosphere. My future research will continue to study legacies of human disturbance on plant communities and organic matter dynamics. Across the globe, shifts from agrarian to industrial economies and associated urban and international migration have led to widespread abandonment of agricultural and pasture lands, with many of these areas reverting naturally to forest cover. Species composition in these secondary forests typically differs from the original forest. My research will address the following questions: How do new species assemblages affect forest ecosystem services? Will original forest composition ever be restored? How do changes in plant species affect soil organic matter dynamics through changes in litter input quantity and chemistry? I am also interested in the social and economic drivers of land use and land cover change, especially in developing countries, and their ecological impacts. I look forward to collaborating with social scientists to better understand the human and ecological context of global environmental change. I also wish to integrate my past experience in terrestrial and aquatic ecosystems to study how natural and anthropogenic disturbances affect losses of carbon and nutrients from soils to waterways and to the atmosphere. I am interested in how deforestation for agricultural use and urbanization alter microbial processes in riparian ecosystems, at the interface between soils and streams. I have been involved in several studies measuring carbon dioxide, nitrous oxide, and methane production in soils, and would like to incorporate soil respiration and greenhouse gas measurements to my future research.

Hydrologic controls on soil organic matter and nutrient transport

The composition and quantity of dissolved organic matter retained or lost from soils has significant implications for carbon sequestration, soil fertility, water quality, and the productivity of riparian and coastal communities. My current postdoctoral research addresses the production, retention, and loss of dissolved organic matter and inorganic nutrients in volcanic forest soils, located intermediate along weathering and rainfall gradients in Hawai'i. I have installed lysimeters in the field under different organic and mineral horizons to track changes in the composition and flux of dissolved organic matter with water flow in the soil. Using microbial incubations, chromatographic (XAD resin fractionation) and spectroscopic techniques (liquid- and solid-state ^{13}C-Nuclear Magnetic Resonance (NMR) spectroscopy), I am characterizing the carbon chemistry and bioavailability of dissolved and solid-phase organic matter. In addition, I am measuring changes in the concentrations of cations and anions as rainwater comes in contact with the plant canopy and enters the soil. The hydrology of these soils appears to drive the transport of labile carbon from the forest floor and zones of highest microbial activity to deeper mineral horizons, where the potential for stabilization is greatest. I am interested in further pursuing how disturbance, such as deforestation, and changes in hydrology and rainfall patterns may alter these processes.

Legacies of land use change on carbon and ecosystem dynamics

While deforestation is still the main trend in the tropics, many areas are in different stages of recovery from past human disturbances. My PhD work addressed the effects of agricultural abandonment and natural reforestation on above- and belowground long-term carbon dynamics. I conducted this NSF-funded study across a replicated chronosequence of secondary forests re-growing on pastures abandoned 10, 20, 30, 60, and 80 years ago. I used field ecological and forest inventory methods to describe forest stand dynamics and found that structural characteristics were recovered in as early as twenty years after pasture abandonment. However, tree species composition remained distinct from primary forests even after eight decades of succession, with significant implications for the amount of carbon stored in aboveground biomass (Marín-Spiotta et al. 2007a). Belowground carbon dynamics did not reflect the increase in aboveground carbon with reforestation. I measured changes in $^{13}C/^{12}C$ ratios in soil organic matter derived from C3 and C4 plants to track changes in the contributions of pasture versus forest litter to soil carbon pools, and estimate rates of carbon gain and loss with reforestation. The gain in new, secondary forest-derived carbon was compensated for by the loss of residual pasture-derived carbon, resulting in no net change in bulk soil carbon pools (Marín-Spiotta et al. *in revision*). Inter-aggregate, unattached, particulate organic matter was more sensitive to land use change than the bulk pool. My research demonstrated the value of combining multi-isotopic and molecular techniques with physical density fractionation methods to yield new insights into the dynamics of belowground carbon sequestration and loss with land-use change. I also collaborated on a leaf and root litter decomposition field study that tested for the effects of litter chemistry versus site quality on decay rates across the same secondary forest chronosequence (Ostertag et al. *in preparation*).

Mechanisms of soil organic matter stabilization

My PhD also addressed the importance of chemical and physical mechanisms of protection from microbial decomposition on soil carbon storage. I applied solid-state ^{13}C-NMR spectroscopy and radiocarbon modeling to density fractions from surface soils to track changes in carbon chemistry and turnover during secondary forest establishment on former pastures. Differences in C and N isotopes, and ^{13}C-NMR spectral intensities showed that the unattached particulate carbon fraction and that located inside soil aggregates represented distinct soil carbon pools with different chemical composition and turnover rates (Marín-Spiotta et al. 2007b and *in revision*). The bulk of the soil carbon pool with longest ^{14}C residence times was recovered in the heavy fraction, providing evidence that mineral association was the dominant stabilizing mechanism. Radiocarbon-based turnover rates of the mineral-associated carbon in secondary forests recovering from abandoned pasture resembled those of primary forests in as little as 20 years, reflecting patterns in aboveground forest stem dynamics. In the active pastures and youngest secondary forests, however, mean residence times of the aggregate and mineral-associated carbon fractions differed from older secondary forests and primary forests, likely due to site differences in plant litter chemistry and soil disturbance (Marín-Spiotta et al. 2007b). I wish to pursue how land use and land cover changes affect the relative importance of physical and chemical mechanisms of organic matter stabilization, with consequences for carbon sequestration and for nutrient retention in soils.

References Cited

Marín-Spiotta, E., R. Ostertag, and W.L. Silver. 2007a. Long-term patterns in tropical reforestation: plant community composition and aboveground biomass accumulation. *Ecological Applications* 17:828-839.

Marín-Spiotta, E., C.W. Swanston, W.L. Silver, M.S. Torn and S.D. Burton. 2007b. Chemical and mineral control of soil carbon turnover in abandoned tropical pastures. *Geoderma* doi:10.1016/j.geoderma.2007.10.001

Marín-Spiotta, E., W.L. Silver, C.W Swanston, and R. Ostertag. Soil carbon gain and loss during reforestation of tropical pastures. *Global Change Biology*. (*in revision*)

Ostertag, R., E. Marín-Spiotta, W.L. Silver, and J. Schulten. Litter decomposition and soil carbon storage along a secondary forest chronosequence in Puerto Rico. (*in preparation for Ecosystems*)