Carbon Cycling in Biomass-Based Cropping Systems: Improving the Mechanistic Foundations of Plant, Microbial, and Soil Interactions

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Project Goals:

The reduction of fossil fuel-derived carbon emissions provided by the emerging bioeconomy represents a critical step toward meeting energy independence goals. Decisions regarding feedstock selection, geographic placement within the landscape, and specific management practices will impact the overall efficacy of ecosystem carbon sequestration and productivity benefits. Therefore, we seek to advance a comprehensive mechanistic understanding of plant-soil-microbe interactions within biomass-based cropping systems that can maximize the potential benefits by providing a more robust framework for predicting ecosystem carbon dynamics. The overarching goal of this project is to use field-based measurements of key ecosystem carbon processes to inform and improve next generation mechanistic ecosystem models.

Abstract text:

The use of plant biomass as feedstocks for bioenergy and bioproducts is expected to offer both economic and ecological benefits over traditional fossil-derived sources. The potential net reduction of carbon emissions is a major environmental advantage of plant biomass-derived feedstocks over fossil fuels. However, the magnitude of carbon emissions reduction within a biomass cropping system depends on upon the efficiency of ecosystem carbon sequestration. Management decisions concerning plant feedstock type, soil tillage, and residue removal rates will likely affect carbon sequestration rates. In addition, the efficacy of ecosystem carbon storage within biomass cropping systems will vary geospatially due to natural differences in edaphic properties. An extensive understanding of interactions between plants, microbes, and soil is required to adequately predict ecosystem carbon dynamics and thus maximize the potential carbon sequestration benefits across the landscape.

A key challenge of studying ecosystem carbon exchange *in situ* is isolating the soil carbon dioxide (CO_2) fluxes from plant root versus soil microbial metabolism. Although the total CO_2 flux can be measured relatively easily at the soil surface, this measurement does not provide any information about the two discrete sources and therefore is less insightful. Since the two sources of CO_2 may have different $\delta^{13}C$ isotopic ratios, they can be separated by measuring $^{13}CO_2$ from soil gas exchange. We will integrate an automated chamber-based soil gas sampling system with an advanced Cavity Ring-Down Spectrometer to provide high-frequency *in situ* measurements of

CO_2 fluxes from both plant roots and soil microbes. This information will help to better understand the underlying environmental and physiological controls on plant root CO_2 respiration, to constrain the quantity of carbon utilized by the soil microbial community, and to calibrate and validate ecosystem-level carbon models.

The soil environment represents the complex interaction of biological, chemical, and physical attributes. These properties have traditionally been simplified within the soil organic matter models that are used to make predictions of soil organic carbon change. Next generation soil organic models explicitly represent many of the complex soil processes, including microbial substrate use, carbon-nitrogen coupling, and physical protection of organic carbon by soil aggregates or mineral surfaces. However, these models have not been thoroughly tested in an agricultural setting, and therefore their performance within biomass cropping systems remains uncertain. We will provide critical empirical data on key soil factors including microbial carbon use efficiency, nitrogen mineralization, and plant root dynamics. We will work closely with model developers to refine and test the improved soil organic matter models using lab and field-based observations. These efforts will result in greater predictive capabilities for carbon sequestration in both biomass-based and traditional row crop agricultural systems.