Effects of Switchgrass Cultivation on Deep Soil Carbon Stock and Long-term Carbon Dynamics in Marginal Lands

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Project Goals: Switchgrass (*Panicum virgatum* L.) is a perennial C_4 grass native to the tallgrass prairies and a most promising feedstock in the U.S. for bioenergy production. Capable of abundant biomass yield with minimal fertilizer or water, switchgrass can survive on marginal soils, and even thrive once established. We hypothesize that successful establishment and sustainable cultivation of switchgrass in marginal soils is in part enabled by beneficial plant-microbial interactions. We are investigating the succession of rhizosphere microbial communities, and ecosystem-scale effects of high- and low-performing switchgrass plants grown in nutrient-limited soils in southern Oklahoma. The outcome of this research will provide a better genomic basis for switchgrass cultivation in marginal soils, expand our knowledge of the interactions between soil microbiomes, plants and ecosystems, and ultimately guide efforts for translation into agronomic row crops.

Accrual of soil organic carbon (SOC) acts as a potential carbon sink, helping to mitigate anthropogenic C emissions. We hypothesize that cultivation of deep-rooted perennial crops, such as switchgrass, could provide long-lasting carbon sequestration, that enhances deep soil C stocks via root biomass inputs. But there may be trade-offs associated with this strategy: the preexisting soil organic matter (OM) pool may be displaced if rates of microbially-stimulated OM degradation increase in response to deep C inputs. In surface soils, many studies have shown 'priming', i.e. that inputs of fresh root biomass and exudates increases OM accessibility and stimulate microbial activity. However, it is unknown whether deep soil mineral-associated organic C (MOC) may be more vulnerable to microbial mineralization under switchgrass cultivation. Our study aims to address this fundamental uncertainty regarding the effects of establishment and sustainable cultivation of switchgrass on deep soil C stocks and long-term C dynamics in marginal lands.

We collected deep core soils (0 to ~3 meters) from two N and P poor sites (silt-loam and clay-loam) in Oklahoma, USA with long-term (>10 years) cultivation of perennial switchgrass and adjacent fields managed with annuals crops. Soil cores were collected from three replicate locations within each site and cropping system. We measured soil C stocks, ^{14}C, ^{13}C and ^{15}N, soil texture and chemistry, root biomass, and microbial community composition. At the silt-loam site with low native SOC stocks, switchgrass cultivation caused a 60-80% increase in the median SOC stock and a shift towards more modern ^{14}C values. At the clay-loam site, where initial SOC stocks where higher, switchgrass root biomass inputs had no significant effect on the overall SOC stock. At both sites, $\delta^{13}C$ of all soil depths increased with switchgrass cultivation, reflecting additional inputs of C_4 organic matter into the soil. Microbial community composition was significantly different with depth at both sites and responded to switchgrass root inputs in the low-carbon site. These results partially support our hypothesis that deep-rooted perennial switchgrass can enhance deep soil C stocks in a relatively short time frame.

In addition to these bulk soil measurements, we set up the long-term monitoring plots in both the silt-loam and clay-loam sites and measured soil respiration monthly between perennial switchgrass plots and adjacent fields managed with annuals crops. We estimated continuous root biomass inputs between topsoil and subsoil layers based on satellite-measured gross primary production (GPP) and measured root biomass distribution with depth. We also measured heterotrophic respiration from a 60-day incubation in the lab using the deep core soils incubated with additional ^{13}C-labeled plant materials. During this incubation, we found that C decomposition was different across sites, root systems, and depths, suggesting that the different responses of soil microbial communities to the root biomass input can result in differential community level C degradation dynamics.

We are currently applying ecosystem modeling to estimate whether root biomass input into the subsoil layer may impact long-term C dynamics and accelerate the old-C (MOC) loss. For this purpose, we improved our MEND (Microbial-ENzyme Decomposition) model to represent multiple soil layers and used it to simulate the C processes along the soil profile. We are now constraining and optimizing the parameters of MEND to fit our observed CO_2 fluxes from the lab and the field. The ongoing model analyses will further project the changes of different C pools for a longer time-period (such as 100 years) to assess the potential release of the relatively stable old-C in deep soils. Our research will provide new insights into the prediction of deep soil C accrual after switchgrass cultivation by comprehensively considering microbially mediated soil C dynamics along the soil profile.

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