Ecosystem responses in switchgrass monoculture stands across a latitudinal gradient

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https://sites.cns.utexas.edu/juenger_lab/switchgrass

Project Goals: As part of a collaborative effort, our project aims to evaluate the potential for sustainable switchgrass (*Panicum virgatum*) production as a biofuel product in North America and better understand the potential ecosystem services associated with large-scale production of perennial bioenergy crops. Specifically, by linking switchgrass growth responses and physiology, belowground plant and microbial activity, and key ecosystem carbon (C) pools and fluxes to variations in climate and edaphic properties, we seek to provide a conceptual mechanistic framework that explains the interactions between switchgrass productivity/morphology/phenology and ecosystem C dynamics.

We explored stand level ecosystem responses of multiple switchgrass cultivars planted along a continental gradient that varied in environmental and soil properties. Stands of switchgrass consisting of 3 lowland cultivars (Alamo, Kanlow, and Liberty) and 3 upland cultivars (Blackwell, Cave-in-Rock, and Carthage) were established during spring 2016 in 6m x 6m plot monocultures arranged in a randomized design with 5 replicates at TX, MO, and IL field sites. Baseline characterization of total soil organic C (SOC), permanganate-oxidizable C (POxC; representing the biologically active SOC pool), and total soil nitrogen (TN) contents to a depth of 2m were determined at the time of planting for each of the sites (Figure 1). Measurements of plant growth, biomass, phenology, and tissue chemistry were coupled with collection of associated soil samples starting at 100% green-up and continuing at 14-20 day intervals through all stages of plant development. To determine the effects of the different physiological and phenological characteristics of switchgrass cultivars on ecosystem dynamics, we measured CO_2 gas-fluxes including net ecosystem exchange (NEE) and soil respiration (R_s) at all sites for Cave-in-Rock and Alamo, representing upland and lowland cultivars respectively. In addition, R_s measurements were made in root exclusion zones to partition heterotrophic from autotrophic respiration (R_h and R_a, respectively). Associated soil samples were analyzed for POxC to investigate plant and seasonal effects on the biologically active SOC pool.

We found initial evidence to suggest that differences in soil properties could lead to variations in long term nutrient availability and sustainability among sites that have not yet been manifested in plant productivity. In MO, where SOC and TN concentrations were lowest, aboveground plant tissues of all cultivars had far wider C:N ratios throughout most of the growing season. Phenological differences were most noticeable between northern sites (IL & MO) and the southern site (TX) where green-up for all cultivars occurred an average of ~50-days later at the northern sites. Flowering times also differed between upland and lowland cultivars, particularly in TX where upland cultivars flowered an average of 68-days earlier than lowland cultivars. In northern sites, lowland cultivars also flowered later (~24-days), and in 2018 Alamo failed to completely senesce before harvest. Overall, after 3-4 years in switchgrass, the active SOC pool was smaller relative to pre-planting levels in TX and IL, and slightly greater in MO where initial total SOC concentrations were already very low. Variations in active SOC among cultivars are evident, however observed patterns are so far not attributable to any definitive environmental factors. Soil respiration differences between the lowland cultivar Alamo and the upland cultivar Cave-in Rock were most noticeable between the IL and MO sites where overall R_s was greater in IL for Alamo, but greater in MO for Cave-in Rock. However, partitioning out R_h from these measurements shows similar R_a for both cultivars regardless of site and suggests greater soil microbial activity in IL relative to MO. In 2018, a noticeable drop in the amount of active SOC at the TX site was linked to a drought that reduced both biomass production and ecosystem respiration, which likely also inhibited root exudation and soil microbial activity compared to the other sites.

These findings suggest that switchgrass ecosystem dynamics are affected by ecotype responses to latitudinal variations in climatic conditions that are also intimately linked with belowground soil C and N processes. Ultimately, understanding the connections between the environmental factors underlying plant and soil linkages may have implications for determining optimal management strategies for the implementation and sustainability of large-scale switchgrass production in North America.

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