Simulating landscape-scale impacts of switchgrass nitrogen use efficiency

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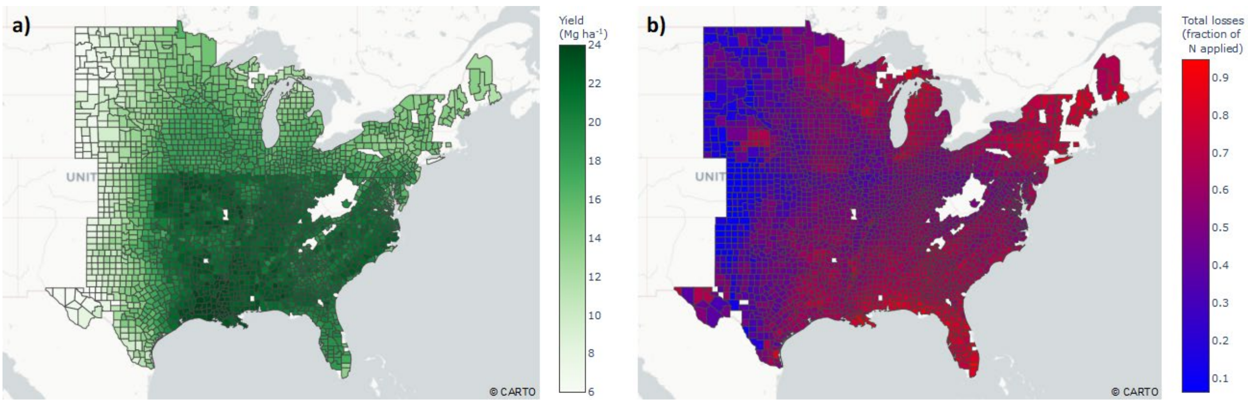
Project Goals: The Center for Bioenergy Innovation (CBI) vision is *to accelerate domestication of bioenergy-relevant, non-model plants and microbes to enable high-impact innovations at multiple points in the bioenergy supply chain.* CBI addresses strategic barriers to the current bioeconomy in the areas of 1) high-yielding, robust feedstocks, 2) lower capital and processing costs via consolidated bioprocessing (CBP) to specialty biofuels, and 3) methods to create valuable byproducts from the lignin. CBI will identify and utilize key plant genes for growth, composition and sustainability phenotypes as a means of achieving lower feedstock costs, focusing on poplar and switchgrass. We will convert these feedstocks to specialty biofuels (C4 alcohols, C6 esters and hydrocarbons) using CBP at high rates, titers and yield in combination with cotreatment, pretreatment or catalytic upgrading. CBI will maximize product value by *in planta* modifications and biological funneling of lignin to value-added chemicals.

Abstract: Biofuels and bioenergy are being actively developed to support rural development, energy independence, decarbonization, and negative emissions. However, it is unclear whether such technologies can be widely deployed at economically and climatically relevant scales without incurring nitrogen (N) pollution in excess of biogeochemical planetary boundaries (1). Dedicated perennial bioenergy crops such as switchgrass tend to utilize applied N more effectively than annual crops due to their well-developed root zones and ability to translocate N and other nutrients belowground into storage at senescence. Targeting production of such crops on marginal land minimizes costs and impacts to conventional agriculture but may imply greater N fertilizer use (2) and higher losses (e.g., leaching) due to the less favorable soils and climates in such areas.

In this work we explore switchgrass yields and N dynamics using the process-based DayCent biogeochemistry model, which simulates the cycling of carbon, water, and N (including mobilization/immobilization, nitrification/denitrification, and related processes) in agro-ecosystems. DayCent has been previously calibrated to represent commercial switchgrass using data from various field trials across the US, including several on marginal lands (3). Here we use that calibrated model to simulate switchgrass production on abandoned croplands across the eastern US (4). In addition to biomass yield, we track key elements of the system N balance (including major loss pathways such as volatilization, denitrification, and leaching) and calculate simulated nitrogen use efficiency (NUE) metrics. N losses from switchgrass cultivation on marginal lands are expected to vary widely as a function of soil texture and climate, suggesting

the need for careful articulation of regionally-specific N application guidelines. Finally, we will present sensitivity analysis results meant to inform breeding efforts and predict how future advanced switchgrass varieties with reduced N requirements and improved NUE might perform across these heterogeneous real-world agricultural landscapes.



DayCent-simulated a) switchgrass yields, and b) fraction of applied N fertilizer lost through volatilization, leaching, and denitrification. These simulations assume non-irrigated switchgrass cultivation on abandoned croplands, fertilized with 75 kg N ha^{-1} annually, and with lowland ecotypes grown below 40°N latitude and upland above.

References/Publications

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