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Carbon and energy balances for cellulosic biofuel crops in U.S. Midwest

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Cellulosic biofuels produced on lands not used for food production have the potential to avoid competition for food and associated indirect land use costs. Understanding the carbon and energy balance implications for different cellulosic production systems is important for the development of decision making tools and policies.

Here we present carbon and energy balances of alternative agricultural management. We use 20 years of data from KBS LTER experiments to produce farm level CO_2 and energy balances for different management practices. Our analyses include four grain and four perrenial systems in the U.S. Midwest: corn (Zea mays) – soybean (Glycine max) – wheat (Triticum aestivum) rotations managed with (1) conventional tillage, (2) no till, (3) low chemical input, and (4) biologically-based (organic) practices; (5) continuous alfalfa (Medicago sativa); (6) Poplar; and (7,8) Successionnal fields, both fertilized and unfertilized. Measurements include fluxes of N2O and CH4, soil organic carbon change, agricultural yields, and agricultural inputs (e.g. fertilization and farm fuel use).

Our results indicate that management decisions such as tillage and plant types have a great influence on the net carbon and energy balances and benefits of cellulosic biofuels production. Specifically, we show that cellulosic biofuels produced from an early successional, minimally managed system have a net C sequestration (i.e. negative C balance) of -841$\pm$46 gCO_2e m-2 yr-1 vs. -594$\pm$93 gCO_2e m-2 yr-1 for more productive and management intensive alfalfa, and vs. 232$\pm$157 gCO_2e m-2 for poplar. The reference agricultural system (a conventionally tilled corn-soybean-wheat rotation) has net sequestration of -149$\pm$33 g CO_2e m-2 yr-1.

Among the annual grain crops, average energy costs of farming for the different systems ranged from 4.8 GJ ha-1 for the organic system to 7.1 GJ ha-1 for the conventional; the no-till system was also low at 4.9 GJ ha-1 and the low-chemical input system intermediate (5.2 GJ ha-1). For each system, the average energy output for food was always greater than that for fuel. Overall energy efficiencies ranged from output: input ratios of 10 to 16 for conventional and no-till food production, respectively, and from 7 to 11 for conventional and no-till fuel production. Alfalfa for fuel production had an efficiency similar to that of no-till grain production for fuel. Our analysis points to a more energetically efficient use of cropland for food than for fuel production, and large differences in efficiencies attributable to management.