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Watershed scale impacts of bioenergy, landscape changes, and ecosystem response

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In recent years, high US gasoline prices and national security concerns have prompted a renewed interest in alternative fuel sources to meet increasing energy demands, particularly by the transportation sector. Food and animal feed crops, such as corn and soybean, sugarcane, residue from these crops, and cellulosic perennial crops grown specifically to produce bioenergy (e.g. switchgrass, Miscanthus, mixed grasses), and fast growing trees (e.g. hybrid poplar) are expected to provide the majority of the biofeedstock for energy production. One of the grand challenges in supplying large quantities of grain-based and lignocellulosic materials for the production of biofuels is ensuring that they are produced in environmentally sustainable and economically viable manner. Feedstock selection will vary geographically based on regional adaptability, productivity, and reliability. Changes in land use and management practices related to biofeedstock production may have potential impacts on water quantity and quality, sediments, and pesticides and nutrient losses, and these impacts may be exacerbated by climate variability and change.

We have made many improvements in the currently available biophysical models (e.g. Soil and Water Assessment Tool or SWAT model) to evaluate sustainability of energy crop production. We have utilized the improved model to evaluate impacts of both annual (e.g. corn) and perennial bioenergy crops (e.g. Miscanthus and switchgrass at) on hydrology and water quality under the following plausible bioenergy crop production scenarios: (1) at highly erodible areas; (2) at agriculturally marginal areas; (3) at pasture areas; (4) crop residue (corn stover) removal; and (5) combinations of above scenarios. Overall results indicated improvement in water quality with introduction of perennial energy crops. Stream flow at the watershed outlet was reduced under energy crop production scenarios and ranged between 0.3% and 5% across scenarios. Erosion and sediment loading at watershed outlet were reduced with bioenergy scenarios except for stover removal scenarios with reduction ranging between 2.4% to 30.5%.

Based on the simulation results for different bioenergy crop production scenario, we have also developed a multi-level spatial optimization framework (MLSOPT) to optimize production of food and energy crops under various sustainability objective functions. The method works in two levels, first level divides large watershed into small subareas and optimum solutions for individually for these subareas are identified. The second level uses these optimum solutions from the first level to identify watershed scale optimum solutions. The framework is tested with a complex spatial optimization case study designed to maximize crop residue (corn stover) harvest with minimum environmental impacts in a 2000 km2 watershed, located in Indiana, USA. In this presentation, results related to optimize sustainability of bioenergy crops will also be discussed.