Bioenergy production in a changing landscape: farmlands in the Southern Appalachians

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Background/Questions/Methods

Exurban development has increased in rural landscapes throughout the US, often at the expense of agricultural lands. Rising demand for bioenergy, an important ecosystem service, has introduced new potential pathways for land-use/land-cover change and may provide a new incentive for farmland conservation. However, the potential for bioenergy production will be affected by changing climate, and development pressure is competing with agricultural land uses. Decision-makers in rural landscapes are faced with conflicting demands for traditional agriculture, exurban development, bioenergy production, and biodiversity conservation. Most bioenergy productivity assessments have focused on global and national scales; few assess scales relevant to regional or local planning. We used a mechanistic plant growth model to simulate bioenergy crop productivity for switchgrass, giant miscanthus, and hybrid poplar under current and future (2050 and 2099) climate scenarios and predict spatial patterns of bioenergy production across an agricultural landscape in the southern Appalachian Mountains. We ask: (1) How does bioenergy crop productivity vary among crops? (2) How is spatial variation in crop productivity related to climate and soil factors? (3) To what extent do hot spots of crop productivity coincide with areas at high risk of conversion to development, and what spatial allocation maximizes bioenergy production?

Results

Bioenergy crop productivity varied substantially among crops across the landscape (range: 0 to 28 Mg/ha/yr). Crops differed in the strength of the relationship between productivity and climate/soil variables. Regression models using only climate variables explained more variance in poplar productivity (54%) than switchgrass (41%) or miscanthus (30%); models using only soil variables explained similar amounts of variance in productivity among crops (switchgrass:49%, miscanthus:42%, poplar:48%). Models containing all climate and soil variables explained 67%, 54%, and 77% of the variance in annual productivity for switchgrass, miscanthus, and poplar ($p<0.001$). Total landscape productivity of bioenergy on agricultural land within the study area ranged from 1.3 million to 1.6 million Mg/yr. The highest landscape productivity was projected under a mixed-crop landscape with the majority of bioenergy production comprised of miscanthus (87,000 ha; 1.5 million Mg/yr) followed by poplar (8,000 ha; 81,000 Mg/yr) and switchgrass (4,000 ha; 66,000 Mg/yr). Of note for regional planning, 55% of land with the highest bioenergy crop productivity was considered at high-risk of development (>80% probability of conversion). Shifting patterns of productivity in response to climate may alter future patterns of competition between ecosystem service provision and other land uses.