Landscape consequences of bioenergy and exurban development scenarios in the Southern Appalachian Mountains

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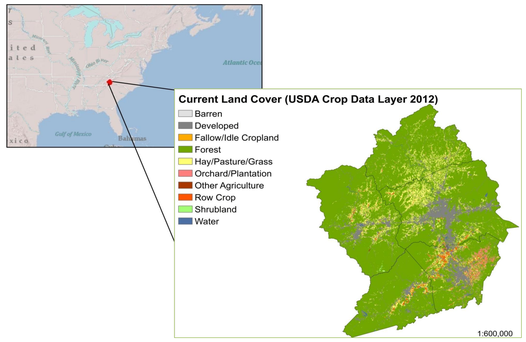
Background

Anticipating the consequences of competing land-use trends remains challenging. Exurban development has increased in many rural landscapes, often at the expense of agricultural lands. Increased demand for bioenergy has introduced a new potential pathway for land-use/land-cover change. Bioenergy crops may provide an alternative for agricultural lands at risk of development and sustain grassland habitat in forest-dominated regions. We explored alternative future bioenergy and development scenarios in the southern Appalachian Mountains. Our study area, the five-county French Broad River Basin in North Carolina has experienced a rapid increase in exurban development, a trend expected to continue to impact rural agricultural and forested lands (Vogler et al. 2010).



Research Questions

1. What is the potential for bioenergy crop production on agricultural lands in western North Carolina?
2. To what extent do lands suitable for bioenergy production overlap with lands at risk of conversion to exurban and suburban development?
3. How do scenarios of bioenergy production and exurban development impact landscape structure and grassland habitat in the study area?

Methods

Estimate switchgrass (*Panicum virgatum* L.) and hybrid poplar (*Populus* sp.) productivity using ALMANAC, a mechanistic model that simulates crop-specific plant growth over time using soil and daily weather data inputs (Kiniry et al. 1996)

Integrate bioenergy crop productivity estimates with an existing parcel-based regional growth model to create seven scenarios that differ with respect to the balance between allocating land uses to bioenergy crops and development. The 2012 USDA Crop Data Layer (30-m resolution) was reclassified using simple rules in ArcGIS™ software to create the scenarios.

Scenario	Rules for Allocating Development and Bioenergy in 2040
"Business-as-Usual" 2040	Maintains existing growth trends, assumes 39% increase in population. Allocates growth based on suitability and probability of development[1].
Maximize Poplar or Switchgrass 2040 (2 scenarios)	Where estimated yield is above 9 Mg/ha/yr, specific bioenergy crop replaces current agricultural land use and future development patterns[2].
Mixed Bioenergy 2040	For each pixel, the highest yielding bioenergy crop type has priority and replaces current agricultural land use and future development.
Marginal Lands: Poplar, Switchgrass, or Mixed 2040 (3 scenarios)	Bioenergy production limited only to agricultural lands not currently in row crop or orchard/plantation production. Includes USDA crop data layer classifications of pasture/hay, fallow/idle cropland, and shrubland.

[1] GroWNC Regional Growth Scenarios 2012 , [2]Biomass Research and Development Board 2008

Results

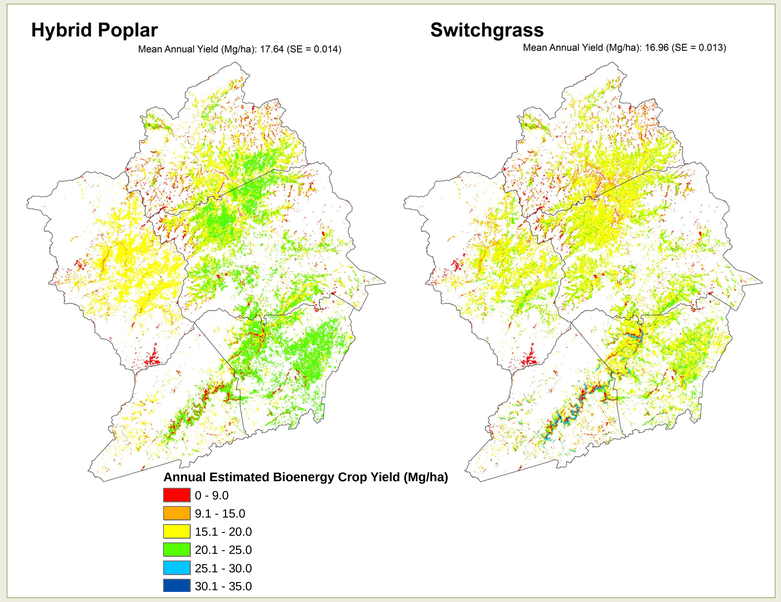


Figure 1. Annual bioenergy crop yield estimated using ALMANAC plant growth model, USDA SSURGO soils data, and daily surface weather from the Daymet database (Thornton et al. 2012). The annual yield (Mg/ha) results suggest that both perennial grass and short-rotation woody bioenergy crops may be suitable in this landscape. In many locations, hybrid poplar outperformed swtichgrass.

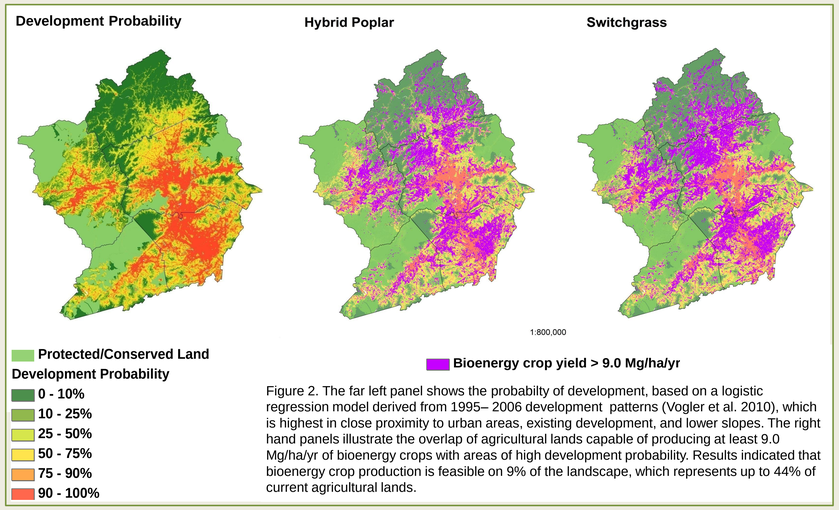


Figure 2. The far left panel shows the probabilty of development, based on a logistic regression model derived from 1995– 2006 development patterns (Vogler et al. 2010), which is highest in close proximity to urban areas, existing development, and lower slopes. The right hand panels illustrate the overlap of agricultural lands capable of producing at least 9.0 Mg/ha/yr of bioenergy crops with areas of high development probability. Results indicated that bioenergy crop production is feasible on 9% of the landscape, which represents up to 44% of current agricultural lands.

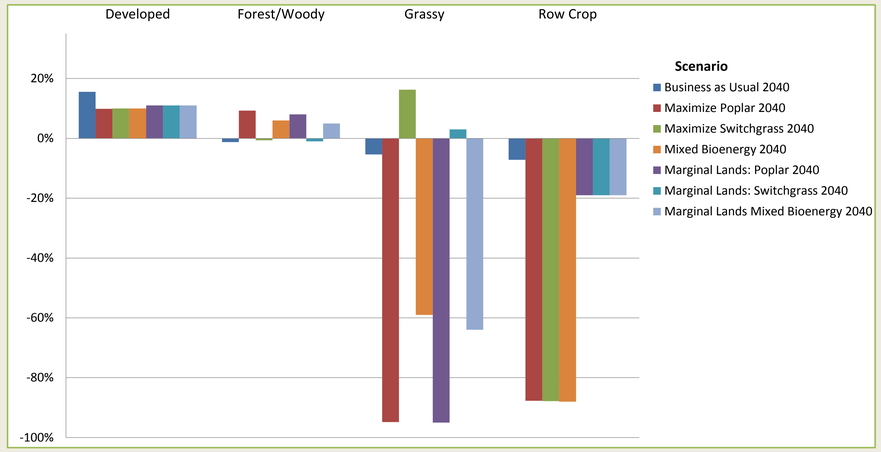


Figure 3. Percent change in land cover composition from current (2012) conditions for the French Broad River Basin across seven development and bioenergy production scenarios.

Table 1. The seven scenarios differ in the estimated annual yield of bioenergy crops, as well as the connectivity of land cover types. Connectivity is measured by the FRAGSTATS CLUMPY index, which ranges from 0 to100% with 0 indicating completely dispersed habitat and 100% indicating completely aggregated habitat (McGarigal et al. 2012).

		Base-line 2012	Business as Usual 2040	Maximize Poplar 2040	Maximize Switchgrass 2040	Mixed Bioenergy 2040	Marginal Lands: Poplar 2040	Marginal Lands: Switchgrass 2040	Marginal Lands Mixed Bioenergy 2040
Estimated Annual Yield of Hybrid Poplar (Mg/yr)		0	0	999,590	0	791,000	873,116	0	698,500
Estimated Annual Yield of Switchgrass (Mg/yr)		0	0	0	967,264	340,828	0	836,650	286,605
Total estimated annual yield of Bioenergy Crops (Mg/yr)		0	0	999,590	967,264	1,131,828	873,116	836,650	985,105
Clumpiness (%)	Developed	69%	67%	67%	67%	67%	67%	67%	67%
	Forest/ Woody	69%	69%	65%	69%	64%	65%	69%	65%
	Grassy	55%	53%	30%	58%	45%	30%	55%	39%
	Row Crop	54%	53%	42%	42%	42%	53%	53%	53%

Summary

As an alternative to development, bioenergy production has the potential to preserve agricultural lands but maintaining habitat area and connectivity for grassland species in mixed bioenergy crop scenarios will require higher amounts of switchgrass than those predicted by simple maximum yield allocation. Scenarios that prioritize maximizing bioenergy crop production result in large decreases in the percent of land dedicated to row crop production (Figure 3). However, limiting bioenergy production to marginal lands may balance tradeoffs among bioenergy production and agricultural production.

Scenarios that prioritized switchgrass production resulted in a 1% decline in forest cover and a 16% increase in grassland habitat. Scenarios that prioritized poplar production resulted higher yields of bioenergy production and were accompanied by substantial declines (up to 95%) in grassland habitat; connectivity of grassland habitat was also reduced. In scenarios that included both switchgrass and hybrid poplar, where priority was given to the highest yielding crop, grassland habitat decreased by 58 to 64% with a corresponding decline in grassland connectivity. A mixture of perennial grass and woody bioenergy crops in this landscape provided higher annual yields than a single crop alone.

A mixture of perennial grasses and woody bioenergy crops in this landscape may be best suited to balance tradeoffs among bioenergy production goals, preserving grassland habitat, and continued agricultural production.

Literature

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Acknowledgments

We thank Christina Dalamangas and Klara Rossouw for their technical assistance. This work benefited from discussions with Ron J. Gehl and John S. King, of North Carolina State University, as well as technical support and input from Jim R. Kiniry and the USDA-ARS Team.

The material presented here is based on work supported by the Biofuels Center of North Carolina, the University of Wisconsin-Madison, Mars Hill College, and the National Science Foundation through the Long-term Ecological Research (LTER) Network.