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Policy incentives for switchgrass production using valuation of non-market ecosystem services

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HIGHLIGHTS

► A linear effective profit model predicts conversion thresholds to switchgrass.
► Carbon and nitrogen fluxes can be valued and incorporated into producer choices.
► Farmgate prices alone of \$51 and \$58/dton switchgrass will entice conversion.
► Reasonable ecosystem service valuations will encourage adoption of switchgrass.

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ABSTRACT

This study presents a linear profit model with combined economic and environmental factors for a switchgrass-for-biofuels agricultural system in the southeastern U.S. The objectives are to establish conversion-to-switchgrass thresholds for various market prices and identify policy incentives that would ensure economic profit while also maximizing environmental benefits (carbon sequestration, displacement of fossil fuels) and minimizing negative impacts (global warming potential, nitrate loss). Weighting factors are chosen to represent incentives and penalties by assigning value to the impacts. With no other incentives, switchgrass market prices of at least \$51 and \$58/dton would be needed in order to make a profitable switch from corn/Conservation Reserve Program (CRP) lands and cotton, respectively. At a mid-range offering of \$50/dton, feasible carbon credit prices of \$3/ \$8/ \$23 per metric tonne CO_2e would incentivize conversion from corn, CRP, or cotton, respectively. Similarly, a water quality penalty of \$0.20/ \$3/ \$2 per kilogram NO_3–N leached would incentivize the same conversions with resultant watershed improvement. At a lower price of \$30/dton switchgrass, incentives based on valuation of ecosystem services begin to exceed feasible ranges of these valuations.

1. Introduction

In order to meet national goals, the next generation of liquid transportation fuels in the U.S. is almost certain to include cellulosic ethanol (CE), the only renewable alternative with near-term viability (Pacheco, 2006). The industry has recently shown signs of forward progress with awards for six commercial-scale refineries distributed by the U.S. DOE in 2007 (Service, 2007) and reductions in the cost of requisite enzyme production (Leber, 2010). Still, biorefineries won't produce CE until a regular supply of feedstock can be assured, making the producer (grower, farmer) a critical stakeholder in the biofuels enterprise. Optimism in the long-term is high, as by reaching the policy goals of biomass fueling 25 percent of U.S. total energy needs by 2025 (commonly denoted as 25 × '25), net farm income is expected to rise by as much as \$180 billion (English et al., 2006). This optimism is based on market forces alone providing the stimulus, but a diversified energy portfolio can be expedited by a combination of market forces and public policy. Furthermore, nearly half of the biomass volume needed to reach these goals is expected to come from the southeastern U.S. (Texas to North Carolina) mostly in the form of perennial grasses (USDA, 2010).

Public policy can be used to provide direct subsidies to dedicated energy crops, thereby influencing the market. In addition, the assignment of monetary value to non-market ecosystem services – carbon sequestration, displacement of fossil fuels, and improvement of water quality – adds another dimension to the tradeoff picture, especially from the grower's vantage point. These services, while currently un-compensated, may be encouraged by the promulgation of tradable permits and credits, or incentivized

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by taxation, which result in an economic value for each service. As these values increase in relative weight to the market price of the product, they become part of the grower's decision to convert lands into crops of increasing environmental value.

Some combination of price subsidies and valuations of ecosystem services thus may be used to incentivize land conversions to biocrops production. This paper examines a range of incentives and the threshold (break-even) values that could be used to promote conversions to switchgrass in the southeastern U.S. if traditional market economics are insufficient.

1.1. Agricultural ecosystem services and land use conversion impacts

Ecosystem services from agriculture, both natural and managed, are those non-compensated goods which benefit society. For our purposes these include, first, climate change mitigation through carbon storage and displacement of fossil fuels. Specifically, the conversion of intensively managed croplands to biofuels can result in U.S. greenhouse gas (GHG) emissions reductions by reducing CO_2 and N_2O emissions, by increased sequestration of carbon in soils, and by replacement of fossil fuels with renewable transportation fuels (25 × '25 Carbon Work Group, 2009). Both observed and modeled data show reductions in overall annual GHG fluxes (net carbon sequestration) of up to 3.8 mt CO_2e/ha ("mt" = metric tonne) for a crop change from cotton to switchgrass (Chamberlain, 2011). Much of this is from decreased fertilization requirements and increased belowground biomass carbon storage. Farm-scale data from switchgrass-for-biofuels research is now becoming available and has focused on net energy benefits of switchgrass versus corn ethanol (Farrell et al., 2006). This research has also estimated the displacement of GHG emissions by replacing conventional gasoline with CE derived from switchgrass (Schmer et al., 2008).

Second, a change in land use also may affect local water quality, as managed production inevitably results in the loss of nitrate via off-farm leaching into surface and ground water. Agricultural inputs make up over 90% of the nitrogen sources resulting in large-scale eutrophication (Doering, 1999). Nitrate loss can be influenced by such diverse factors as crop type, tilling practices, timing of harvest, rainfall and soil type, but conversion from tilled, N-intensive crops to perennial grasses will generally result in a reduction of nitrogen loss (Costello et al., 2009).

Voluntary carbon credit and nitrogen trading programs are proliferating at the state and watershed level (Congressional Research Service (CRS), 2008); (Breetz, 2004).

Though the regulatory driver is often a Federal mandate, such as the Clean Water Act, state governments have provided the impetus to establish compliance groups of members who have the option of buying or selling credits in order to meet emission guidelines. These programs provide opportunities for farmers to sell offsets to point source emitters in order to mitigate excessive discharges. Water quality trading has been officially encouraged since 2003 (via U.S. EPA policy) as a way of meeting effluent limits within a watershed (Kibler and Kasturi, 2007). Some Federal programs, such as the EQIP program, provide financial incentives for the more general goal of conservation which includes a reduction of nitrate runoff (Doering, 1999).

1.2. Economic decision-making and valuation of carbon and nitrogen fluxes

Switchgrass production in the southeast is currently limited to pockets of farms relying on research dollars for small-scale demonstrations, such as in eastern Tennessee (Goddard, 2009). Recent surveys have shown that a grower's reluctance to grow switchgrass is largely driven by opportunity costs of converting profitable land out of current use and the uncertainty of long-term land usage contracts (Jensen et al., 2007). Switchgrass production is not much different from other traditional crops grown from seed and can utilize machinery and farm implements currently used for the production of hay. Nonetheless, in order for growers to begin planting a new perennial crop they need some assurance of increased net profits over a foreseeable future, and preferably for the life of the crop. Long-term price assurance is a necessary condition for the development of a secured supply for biomass conversion plants in the long run (Bocquého and Jacquet, 2010).

Investigations on traditional crops reveal optimal levels of a management strategy, such as irrigation input (e.g., Carpio and NeSmith, 2006), that will maximize profits for a particular cropping scenario. These examples, however, do not incorporate environmental impacts, both positive and negative, that might accrue from intense growth of biofuels at profitable levels. Land conversion into bioenergy crop production may or may not represent a significant carbon sink depending on the previous land use (Fargione et al., 2008; Searchinger et al., 2008). Both carbon sequestration and nitrate losses should be referenced to a baseline, or "business-as-usual" scenario, in order to have relevance. Thus, there are environmental opportunity costs and benefits as well. These become part of a producer's decision-making only if they represent a portion of total cost or revenue.

The two ecosystem functions of agriculture relevant to our study – climate regulation and nutrient cycling – involve the management and valuation of carbon and nitrogen compounds (Costanza, 1997). Carbon emissions can either be regulated via market-based allowance trading mechanisms or a carbon tax/fee. For example, the voluntary-membership Chicago Climate Exchange (CCX) recently (until last year) issued agricultural soil carbon offsets based on a measured or projected GHG flux over a designated life span (Martinez-Alier et al., 2010), relative to a baseline scenario (Chicago Climate Exchange (CCX), 2009). Upon verification of annual contractual obligations, holders can cash in their offsets at the current market price on the exchange. A U.S. carbon cap-and-trade market, similar to the Emissions Trading Scheme (ETS) in Europe, would presumably establish a lucrative market for carbon sequestration projects. Although mandatory trading schemes do not currently exist in the U.S., recent Congressional debates suggest that it may be a possibility in the future. Recently proposed U.S. federal legislation (the "Waxman–Markey Bill") would limit total emissions while allowing regulated industries to purchase additional carbon offsets from EPA-approved projects, including agricultural sequestration (Sheppard, 2010). As an alternative, a carbon tax or fee would arguably be a more transparent, efficient method with lower transaction costs and more certainty for long-term planning (McKibbin and Wilcoxen, 2002). The resultant effect to the agricultural producer would be the same, amounting to either a credit or loss for carbon flux. A bill recently introduced in the U.S. Congress (Save Our Climate Act) would set a graduating fee on carbon at the point of entry into the economy, beginning at $10/ton CO2, with a gradual increase of $10 per ton each year (U.S. House of Representatives, 2011).

Taxation or fee is also sometimes proposed as a policy tool to reduce the loadings of a contaminant, such as nitrate–nitrogen, from both point and nonpoint sources. High nitrate runoff rates are responsible for such impacts as loss of ecosystem biodiversity and eutrophication of receiving coastal waters (Galloway et al., 2002). Application of an indirect nitrogen tax (not directly tied to the level of pollution), such as on the purchase of fertilizer and/or animal feed, has the effect of reducing the leaching potential by encouraging the planting of less nitrogen-intensive crops. The tax of 100% on the cost of nitrogen fertilizer would result in a 32–40% reduction in effective nitrogen applications as modeled in Denmark (Schou et al., 2000), but a study in the U.S. estimated that a 500% tax would be needed to provide a similar reduction in the Mississippi watershed