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Impact of environmental values on the breakeven price of switchgrass

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ABSTRACT

This study estimates the farm-gate breakeven price of switchgrass relative to wheat in Oklahoma, USA. The breakeven price of switchgrass is determined for two situations: when external consequences are ignored and when the environmental costs of changes in soil erosion, fertilizer (nitrogen and phosphorous) runoff, and soil organic carbon (SOC) are considered. Results suggest that if indirect land use changes are ignored, the farm-gate breakeven price of switchgrass when only the internal costs are considered is 69%–144% greater (depending on land quality) than if the value of selected external consequences are considered. The potential environmental benefits are greater if highly erodible land is switched from annual cropping to switchgrass.

1. Introduction

With concern over environmental degradation there has been interest in finding alternative sources of energy across the globe. Part of this interest has focused on renewable bioenergy, which is expected to have fewer negative environmental consequences than hydrocarbon fuels. Among the many potential dedicated energy crops, switchgrass has considerable promise due to its ability to grow on many different types of soil under diverse climatic conditions. Switchgrass is a perennial native grass of North America, where it naturally occurs over an area between 20° N and 55° N and 65° W to 98° W. Switchgrass is a drought and flood tolerant perennial lignocellulosic crop that can produce substantial biomass yields with relatively little chemical fertilizer. As roots expand into the deep subsoil for nutrients and water, switchgrass can deposit organic matter within the soil profile resulting in increasing the soil organic matter. It also provides cover to the soil from the erosive force of wind and rain that reduces erosion relative to continuous cropping with annual crops. There are additional environmental benefits derived from reducing nitrogen and phosphorous runoff [1]. Since 1991 switchgrass production has received special attention in US when the US Department of Energy declared switchgrass as a model herbaceous energy crop [2].

Switchgrass has been evaluated as a potential biomass crop in several countries. Monti et al. [3] did an economic feasibility study of switchgrass production under several scenarios in Italy and found that the relative yield of

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switchgrass would have to be increased to enable it to compete for land with maize and alfalfa. However, they did not consider the positive environmental benefits derived from the switchgrass production. Smeets, Lewandowski and Faaij [4] found that switchgrass was a promising bioenergy crop for the European Union mainly because of yield, low production costs, and improved environmental outcomes relative to conventional crops. Samson and Omielan [5] concluded that in Canada switchgrass has significant potential to be a feedstock for the cellulosic ethanol industry and could be a major contributor in reducing Canadian CO_2 emissions. Dam et al. [6] analyzed the environmental impacts of large-scale biomass production from soybeans and switchgrass in Argentina. They found that switchgrass accumulated more carbon than soybeans and resulted in lower soil loss. They concluded that greatest potential environmental benefits could be achieved by producing switchgrass on abandoned cropland. Ichizen et al. [7] and Ma et al. [8] showed that switchgrass is effective in preventing soil erosion in one of the most arid region of the Loess Plateau in China. The projected potential for switchgrass feedstock production raises several research questions. First, what net price for switchgrass would be required to bid land from its current use to switchgrass production? Second, what are the expected changes in soil erosion, fertilizer (nitrogen and phosphorous) runoff, and soil organic carbon (SOC) from converting crop land into switchgrass production, and what is the expected economic consequence of these changes? In this research study, we estimate selected environmental benefits derived from the conversion of land used to produce winter wheat for grain to the production of switchgrass biomass for biorefinery feedstock.

The US Environmental Protection Agency (EPA) using the Forestry and Agriculture Optimization Model (FASOM) predicted that by 2022, it would be economically feasible to produce 3.4×10^9 m^3 of biofuel from switchgrass biomass feedstock [9]. The FASOM model also projected that most of the switchgrass feedstock would be grown in Oklahoma replacing wheat and hay production. Therefore, based on EPA's finding we consider Oklahoma as our study region.

Several studies have estimated the production costs of switchgrass biomass. Mooney et al. [10] determined the breakeven price of switchgrass for four different locations in Tennessee. They found that the farm-gate breakeven price of switchgrass based on 10-year production contracts was 46 $ Mg^{-1} for an average yield of 17.7 Mg ha^{-1} and 69 $ Mg^{-1} for an average yield of 8.5 Mg ha^{-1}. Khanna et al. [11] estimated the Illinois farm-gate breakeven price of switchgrass to be 98 $ Mg^{-1} with average yields of 9.42 Mg ha^{-1}. Epplin et al. [12] found that under a land-lease contract in Oklahoma, the estimated cost of switchgrass production was 41 $ Mg^{-1} under an assumed eight-month harvest window. The cost increased to 58 $ Mg^{-1} when the harvest window was restricted to two months per year. In Tennessee, based on farmer bids, the cost of producing switchgrass ranged from 40 $ Mg^{-1} to 60 $ Mg^{-1} assuming that an average yield of 15.70 Mg ha^{-1} could be obtained. McLaughlin and Kszos [13] estimated US farm-gate prices of switchgrass of 30 $ Mg^{-1}, and 44 $ Mg^{-1} for average yields of 11.4 Mg ha^{-1}, and 9.4 Mg ha^{-1}, respectively. These studies did not consider the environmental consequences of producing switchgrass relative to existing land use and also did not place any monetary value on those consequences while estimating the farm-gate breakeven price of switchgrass.

Nelson et al. [14] discussed the environmental consequences of converting conventional crop land to switchgrass. They used the Soil and Water Assessment Tool (SWAT) watershed-scale water quality model [15–17] to determine the environmental outcomes of switchgrass production. They simulated switchgrass yields and other commodity crop yields and estimated the farm-gate breakeven price of switchgrass. Graham et al. [18] used the Environmental Policy Integrated Climate (EPIC) field-scale environmental model [19,20] to predict switchgrass and other alternative crop yields and their associated environmental outcomes. They determined the farm-gate breakeven price of switchgrass by comparing it to the production of other alternative crops. Both of these studies found that switchgrass production reduced soil erosion and nutrient loss compared to annual crops. King et al. [21] also found that switchgrass production reduced soil erosion and nutrient loss. However, these studies did not attach any monetary value to the environmental benefits derived from converting to switchgrass production while estimating the farm-gate breakeven price of switchgrass. Production practices budgeted to estimate in the recognition that the environmental consequences of biomass production from a dedicated energy crop such as switchgrass would be locally specific to the region surrounding the biorefinery constructed to process the feedstock. In addition, the environmental consequences would differ depending on the quality of the land used for producing the biomass and on the current use of the land.

The primary objective of this study is to determine the site-specific farm-gate breakeven price of switchgrass for two situations: (1) when external consequences are ignored and (2) when the environment costs of changes in soil erosion, fertilizer (nitrogen and phosphorous) runoff, and SOC are considered. To achieve the objective it is necessary to estimate the expected yield of switchgrass and grain-only wheat and the expected differences in nitrogen loss, phosphorous loss, soil loss, and changes in SOC for alternative soil classes over a multi-county area.

The landowners' decision regarding shifting into a long-term investment such as switchgrass by replacing an existing annual crop depends on the relative expected returns. Since no formal market exists for switchgrass biomass, the opportunity cost of producing switchgrass is estimated from the returns of the best alternative crop, which is wheat in the study region.

This study is divided into three sections: (1) the EPIC model, which was used to simulate the expected yield of switchgrass and wheat along with the environmental outcomes including (a) total soil loss (Mg ha^{-1}), (b) nitrogen loss (kg ha^{-1}), (c) phosphorous loss (kg ha^{-1}), and (d) changes in SOC (kg ha^{-1}); (2) an economic model, which was used to estimate the farm-gate breakeven price of switchgrass when external consequences are ignored, and (3) the farm-gate breakeven price of switchgrass, which was estimated as a function of the environmental costs of soil erosion, fertilizer (nitrogen and phosphorous) runoff, and SOC depletion.