Assessing the Cost of Supplying Alternative Dedicated Energy Crops for Biofuel Production in Tennessee

T. Edward Yu, James A. Larson, and Burton C. English
Department of Agricultural & Resource Economics
University of Tennessee

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INTRODUCTION

The development of a bio-based fuels and power sector using lignocellulosic (LCB) feedstocks is currently a major focus of bioenergy sector development in many states. Among others, the Tennessee Biofuels Initiative (TBI) is a state sponsored program that committed $70 million to develop an LCB-based energy sector in Tennessee. The development of conversion technologies for LCB-based biofuel production at a pilot biorefinery created under the TBI has stimulated the envision of establishing a commercial-scale biorefinery in Tennessee in the near future .

In addition to the progress in conversion technology, the supply chain system of biomass feedstock is crucial to the development of the cellulosic biofuel industry because of the importance of the quality and quantity associated with the bulky feedstock to the biofuel conversion process. Improving the efficiency of supply chains providing LCB feedstock to biorefineries is crucial to the commercialization of a LCB-based biofuel industry.

OBJECTIVES

Given the potential for developing a commercial-scale biofuel industry in Tennessee, this study aims to evaluate the suitability of alternative feedstocks for biofuel production in the state considering the feedstock cost at the gate of a biorefinery. Our specific research objectives are to:

1. provide a more comprehensive estimate of plant gate costs of two dedicated energy crops, switchgrass and energy sorghum
2. assess differences in land use change for producing those two dedicated energy crops, and
3. determine the optimal location of biorefinery with the least feedstock cost and associated feedstock draw area in Tennessee

ANALYTICAL MODEL

- A spatially-oriented, mixed-integer mathematical programming model, the Bio-Energy Site and Technology Assessment (BESTA), was used.
- The objective was to minimize plant-gate cost of production, harvest, storage, and transportation of feedstock to the biorefinery, subject to constrains on feedstock production availability and the demand for feedstock by the biorefinery.
- Decision variables: the amount of feedstock produced, stored and transported in a spatial unit by month, the location of the biorefinery, and the feedstock draw area.

MODEL ASSUMPTIONS & DATA

- The capacity of a commercial-scale and single-feedstock biorefinery is 50 million gallons of biofuel per year (MGY).
- Feedstocks are harvested once per year using the large square bale (LSB) system.
- Dry matter losses for storage periods up to 365 days are modeled for the LSB systems.
- Potential locations for the biorefineries are limited to feasible industrial parks with access to water, power, and roads, as well as sufficient storage space in each region (see Figure 1).
- The resolution of crop zone is 5 square miles.
- Traditional crop yields are from the SSURGO database at the sub-county level in USDA/NASS; area of each traditional crop in a crop zone is derived from the cropland layer database in NASS.
- Yield of mature switchgrass from Oak Ridge National Lab ranges 8.0 ─ 9.4 dry ton/acre (see Figure 2), while the yield of energy sorghum ranges 6.0 ─ 9.0 dry ton/acre in Figure 3.

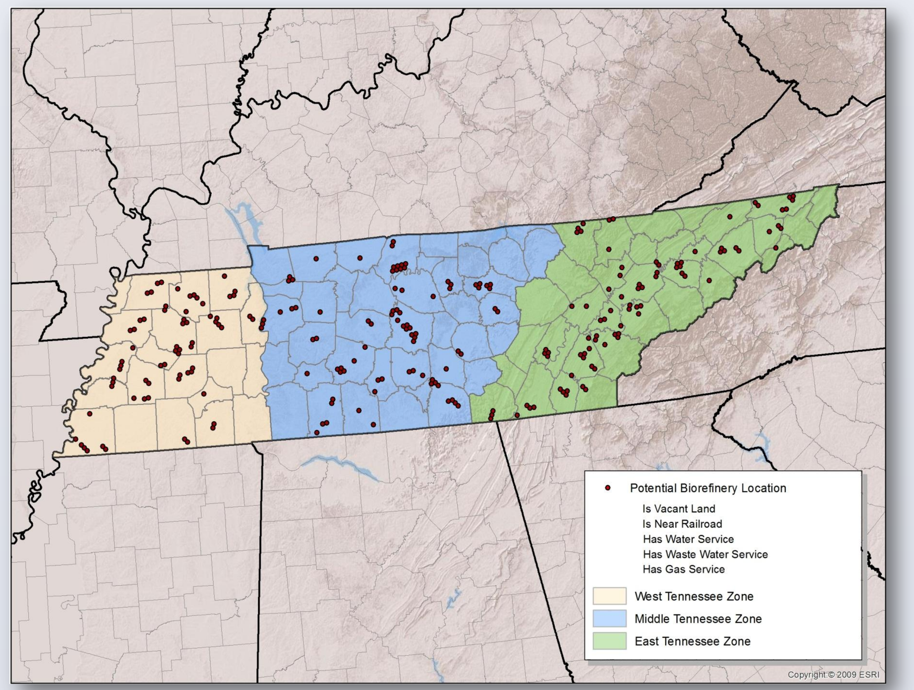

Figure 1. Potential industrial parks to site biorefinery

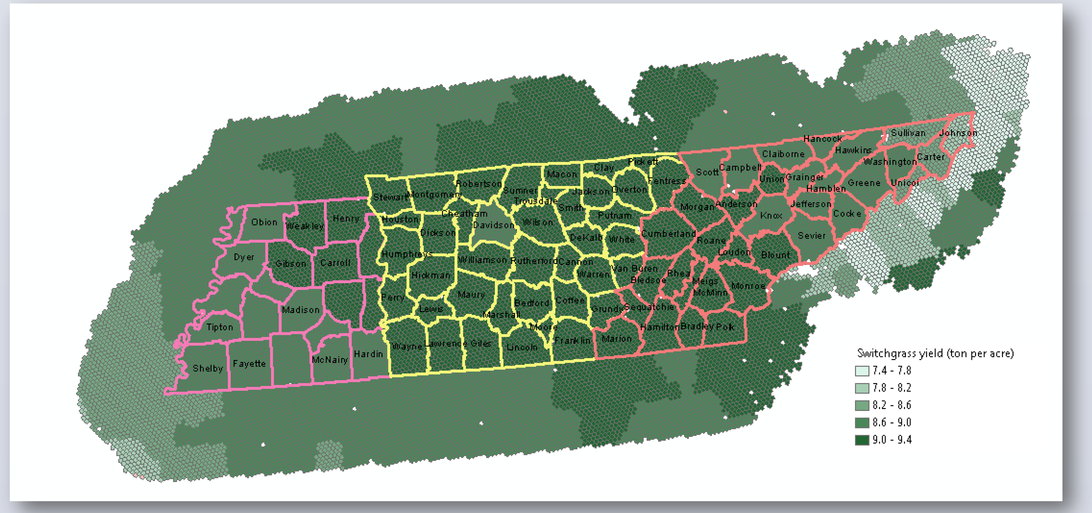

Figure 2. Potential yield of switchgrass

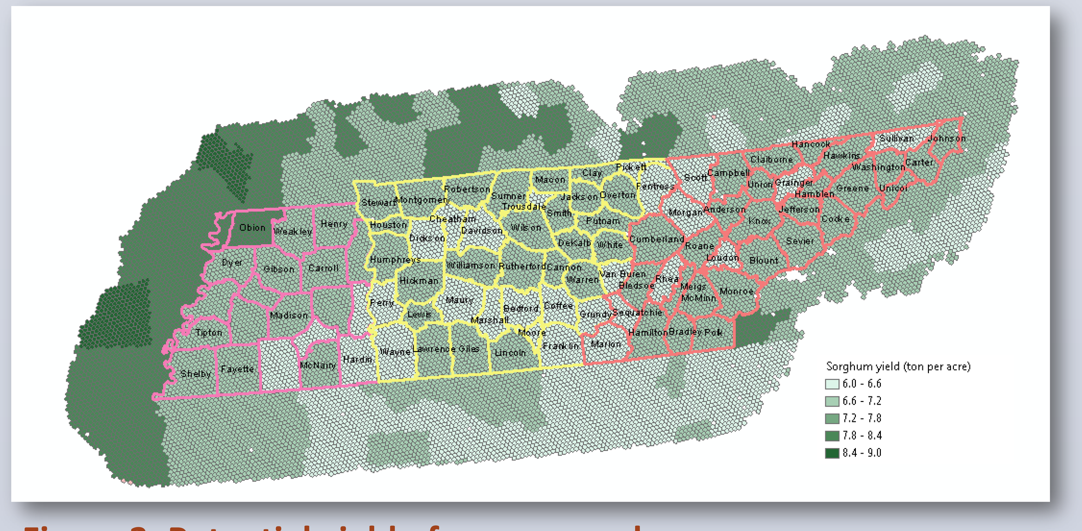

Figure 3. Potential yield of energy sorghum

EMPIRICAL RESULTS

Figure 4 summarizes the optimal plant-gate costs of feedstock for a 50-MGY biorefinery using the LSB system by region. Using switchgrass as feedstock has significant cost advantage when comparing to energy sorghum, primarily due to the differences in production cost between the perennial grass and annual crop.

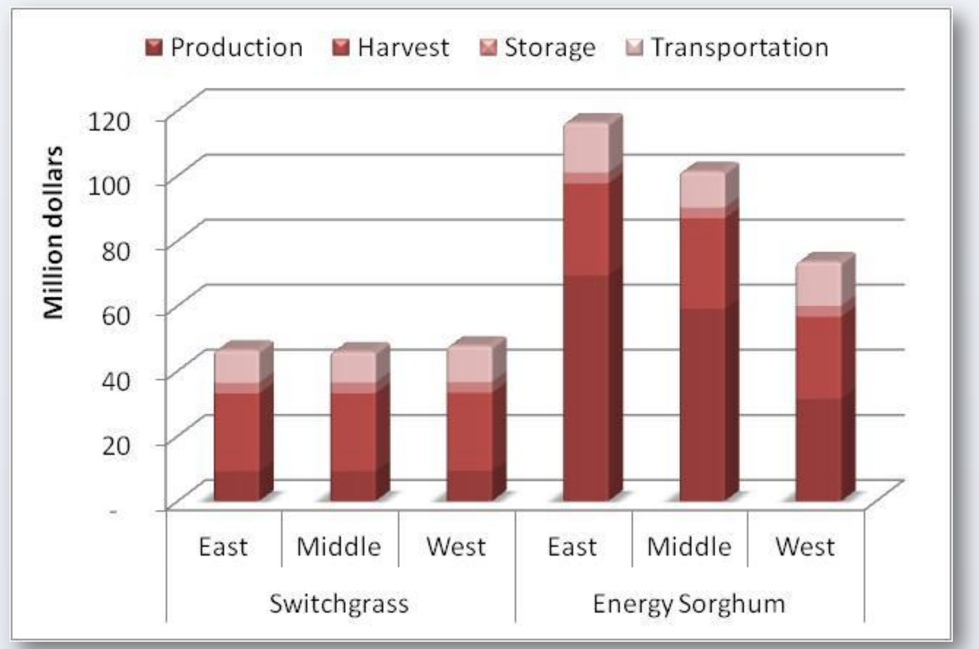

Figure 4. Plant-gate cost of LCB feedstock by region

Figure 5 presents the land use change due to feedstock production. About 80,000 acres of switchgrass were produced to support the 50-MGY biorefinery in each region, primarily converted from pasture and hayland. As an annual crop, the land used for energy sorghum was mainly converted from corn and cotton. Also, the relative lower feedstock yield demanded more crop areas.

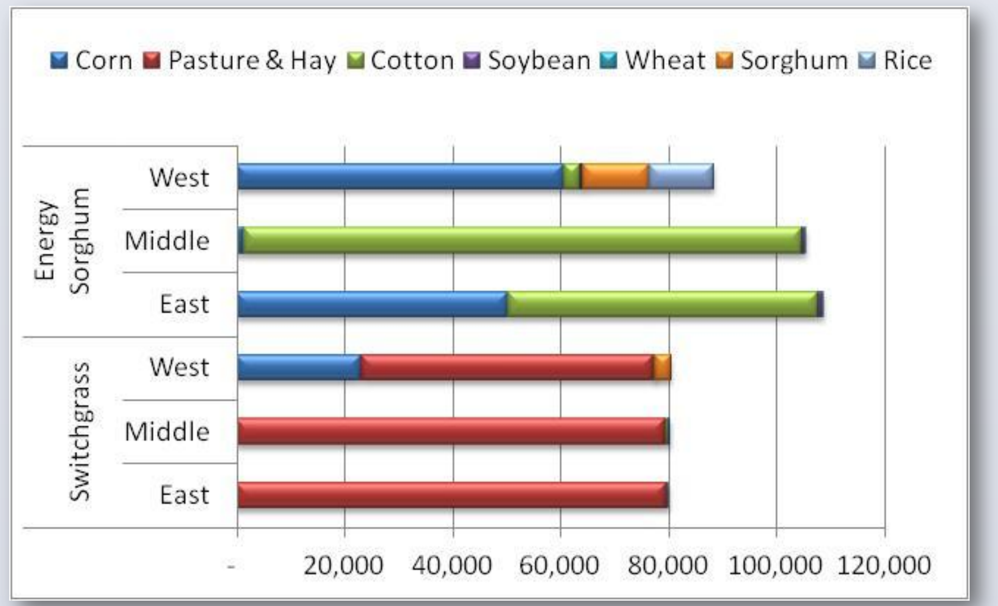

Figure 5. Land use change in acres for LCB feedstock production

Assuming the yield of energy sorghum doubled (i.e. 12-18 dry tons/acre), Figure 6 shows that its plant-gate cost and planted area reduced considerably. However, the declines in cost from yield improvement are still not competitive with switchgrass in Figure 4.

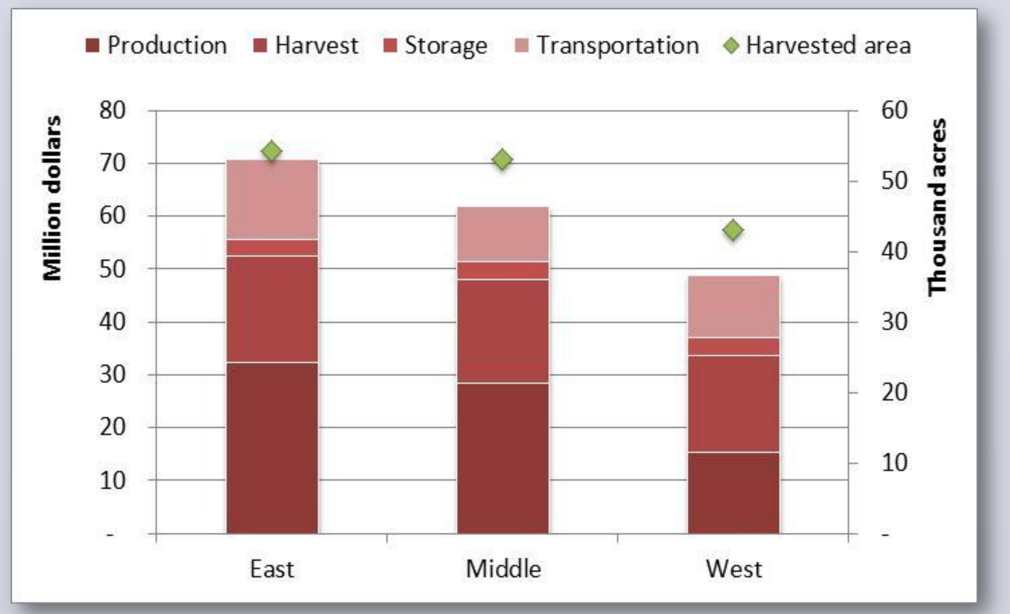

Figure 6. Total plant-gate costs and land used for energy sorghum by region when its yield doubled

Figure 7 presents the optimal location of the 50-MGY biorefinery with the least plant-gate costs of both feedstocks by region. The respective draw area of switchgrass and energy sorghum for the most optimal site in Tennessee is presented in Figure 8.

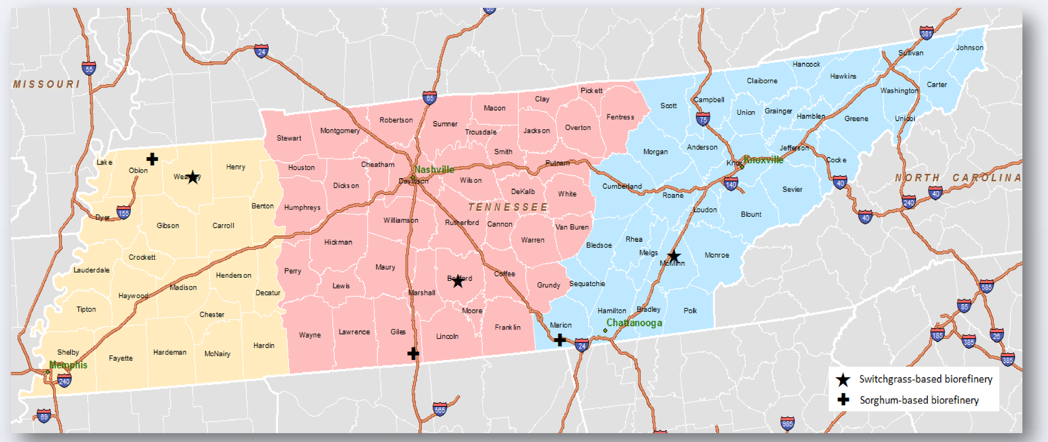

Figure 7. The optimal site of a 50-MGY biorefinery converting switchgrass and energy sorghum by region

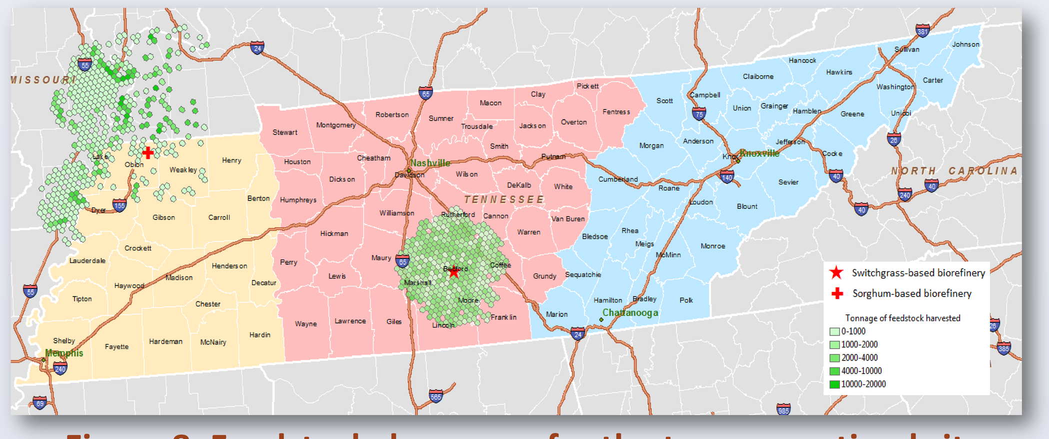

Figure 8. Feedstock draw area for the top one optimal site of a 50-MGY biorefinery in Tennessee

CONCLUSIONS

This study evaluated the cost of producing, harvesting, storing, and transporting two types of dedicated energy crops, switchgrass and energy sorghum, for a single-feedstock biorefinery n east, middle and west Tennessee. Our results suggest that:

- From an economic standpoint, switchgrass is more feasible as a feedstock when compared to energy sorghum for cellulosic biofuel production in Tennessee.
- The inputs required to produce an annual crop, such as energy sorghum, are more than for switchgrass.
- Short of available crop land and the less fertile soil area, particularly in east Tennessee, generate a larger feedstock draw area for energy sorghum.
- The biorefinery located in Bedford County in middle Tennessee is suggested to be the most preferred site to establish a switchgrass-based biorefinery, while the most suitable site for a biorefinery using energy sorghum as feedstock is located in Obion County in west Tennessee.

AKNOWLEDGEMENT

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[1]Corresponding author:

T. Edward Yu, Agricultural & Resource Economics, University of Tennessee, tyu1@utk.edu