Yield and Production Costs for Three Potential Dedicated Energy Crops in Mississippi and Oklahoma Environments

Authors: David Busby[a], Randall D. Little[a], Saleem Shaik[a], Angelina Martins[b], Francis Epplin[b]
Seonghuyk Hwang[b], Brian S. Baldwin[c], Charles M. Taliaferro[d]

[a] The Department of Agricultural Economics, Mississippi State University
[b] The Department of Agricultural Economics, Oklahoma State University
[c] Department of Plant and Soil Science, Mississippi State University
[d] Department of Plant and Soil Science, Oklahoma State University

CORRESPONDING AUTHOR: **DAVID BUSBY**
205 Lloyd-Ricks, West Wing
Dept of Agricultural Economics
MSU, Mississippi State, MS-39762
Phone: (662) 325 0872; Fax: (662) 325 8777
E-mail: dpb24@msstate.edu

Selected Paper prepared for presentation at the Southern Agricultural Economics Association Annual Meeting, Mobile, Alabama, February X-X, 2007

ABSTRACT

The objective of this paper is to determine production costs of switchgrass, eastern gammagrass, and giant miscanthus using Mississippi and Oklahoma data. Production costs were computed using a standard enterprise budgeting approach by species and method of harvest. Results indicate cost difference across species and method of harvest.

Keywords: Yield and Cost, biomass species

David Busby

Yield and Production Costs for Three Potential Dedicated Energy Crops in Mississippi and Oklahoma Environments

I. Introduction

The world has relied on nonrenewable fuel sources since the start of the Industrial Revolution. Like much of the developed world, the United States has become dependent on nonrenewable resources such as nuclear, coal, and crude oil, as major sources of energy and fuel. Over the years, technology has been improved to provide a way for crude oil to be economically refined into gasoline and diesel fuel for use in automobiles. Gasoline and diesel powered vehicles have become the primary method of transportation for people and for shipping goods around the world.

With countries becoming more specialized in the production of goods, the increasing need of trade has created a greater dependence on transportation systems. With crude oil as a cheap and abundant source of energy and fuel, the United States has developed a dependency on oil and more importantly, imported oil. In 1973, the United States produced 3.4 billion barrels and imported 1.2 billion barrels of crude oil. By 1993, the United States had reduced oil production to 2.5 billion barrels while increasing the amount of imported oil to 2.5 billion barrels of crude oil (U.S. Department of Energy). By 2004, the United States has increased imported oil to 3.7 billion barrels of crude oil and limited production to 2.0 billion barrels of crude oil (U.S. Department of Energy).

The dependence on imported crude oil has caused the United States to assess the economic viability of renewable fuel sources. Recent high crude oil prices have prompted policy makers to explore ways to become less dependent on imported oil. As of 2004, the United States imported 65% of its crude oil. Ethanol along with other alternative energy sources could help to replace more than 75% of oil imports to the United States (Bush).

Nonrenewable resources currently used to produce energy bear a cost to society as pollution is emitted into the environment. Externalities such as air pollution and unclean water are the by-products of using nonrenewable resources to produce energy. Ethanol provides a cleaner alterative renewable fuel source (State of the Union 2006).

Another issue that has arisen is the future use of land currently placed in agriculture retirement programs. If the land in the agriculture retirement programs is removed from these programs, much of it will likely again be cultivated. With the resulting increase in production, farming entities will create a surplus of agricultural commodities which will cause the prices of the commodities to decline. This will very likely increase government expenditures on support programs and/or force individual farm size to increase in land acres and push many smaller farming entities out of production. In contrast, using the land to grow biomass feedstock could prevent these lands from reentering cultivation.

In recent years, technology has been developed to convert grasses with high cellulose content into ethanol for use as a fuel source. Ethanol produced from grass biomass is a cleaner fuel source than the currently used nonrenewable fuel sources. Grasses could be grown on land that is currently idle under the agricultural retirement programs. Previous research has identified Switchgrass, Giant Miscanthus, and Eastern Gammagrass as potential biomass feedstock based on the ease of production, cost of establishment, and yield. The general objective of this research is to estimate production per acre of Switchgrass, Giant Miscanthus, and Eastern Gammagrass accounting for the number of harvests. Next, utilizing the theory of duality between primal production and dual cost function, estimate the associated production cost based on the estimated production per acre by species. The specific objectives are to:

1. Estimate production functions to
    a. Determine differences in production per acre based, on species.
    b. Determine differences in production per acre based on number of harvests per year (one or two).
2. Determine cost per acre and cost per ton to produce each biomass species.

The major objective of this paper is to estimate production per acre and associated cost by biomass species utilizing the theory of duality between production and cost function. A literature review related associated with production and cost from the agronomic point of view under ethanol, lignocellulosic biomass and cost of production is presented. The specification and econometric estimation of the production and cost functions is presented in the third section. The description of the data is also detailed in the third section. The application and results are presented in the fourth section followed by summary and conclusions.

II. Literature Review

Ethanol

Technological advancements have allowed scientists to process natural renewable resources into ethanol to be used as a fuel source. This technology along with a more environmentally minded consumer, attempts for America to become more oil independent, and tax incentives have lured car manufactures into developing cars that run on ethanol/gasoline blends, such as E85 which is 85% ethanol and 15% gasoline, and pure ethanol. According to the U.S. Department of Energy (DOE), people in some major cities throughout the United States have been purchasing an ethanol blend, gasohol, as fuel for cars. Gasohol is a blend of 10% ethanol and 90% gasoline. Ethanol is predominately distilled from agriculture grains, corn in particular. The DOE is also exploring ways to develop ethanol from other sources, including agriculture waste and feedstocks such as switchgrass and corn stover.

Tembo, *et al.* identify that the increase in ethanol production is due to public policies subsidizing it as a fuel substitute and the use of fuel additives containing oxygen molecules in specific parts of the United States to improve the atmosphere. The Clean Air Act Amendments of 1990 pushed to use alternative fuels or oxygenated gasoline in cities with high levels of carbon monoxide. Ethanol and MTBE (methyl tertiary butyl ether) are primary oxygenates; however discoveries have been made that MTBE can contaminate ground water (US DOE).

The Renewable Fuel Association (RFA) has outlined some of the Federal tax incentives that benefit producers. Small producers are credited $0.10/gallon production income tax credit up to 15 million gallons per year. Gasoline and ethanol blenders can receive a $0.51/gallon tax credit, a $0.054/gallon tax exemption for alcohol based fuels, and income tax deductions for the purchase of alcohol-fueled vehicles. The House of Representatives and Senate are both working on legislation that would increase the production of ethanol such as Bill number H.R. 4573, H.R. 4673, S. 1994, and S. 650 just to name a few.

Ethanol production has increased from 175 million gallons in 1980 to 3.64 billion gallons in 2005 with 754 million more gallons of capacity under construction (RFA). The ethanol industry is expected to more than double in size by 2012 to meet the renewable fuel production mandates set by legislation (Kenkel and Holcomb). One gallon of ethanol contains 38% Btu less than one gallon of unleaded gasoline with gasoline containing 125,000 Btu.

Lignocellulosic Biomass

Lignocellulosic Biomass (LCB) is a compound of several different types of sugars that can be fermented to high value products. LCB is composed of 15-25% lignin, 23-32% hemicellulose, and 38-50% cellulose (Jarvis). Several different types of LCB have been and are being studied and tested to see if ethanol could be produced and how much could be produced. According to Thorsell, *et al.* using several different feedstocks has many potential advantages. The wide variety of feedstocks would allow a longer opportunity to harvest LBC and be able to reduce the fixed costs of the harvesting equipment per unit of feedstock. Thorsell, *et al.* also points out that an assortment of perennial grass would enable a diversified landscape and would reduce the potential for insect and disease risk inherent with monocultures and that the perennial grasses could be grown on land unsuitable for grain production.

Bransby, Sladden, and Downing studied how a commercial harvesting and baling density of Alamo switchgrass affected yield. They set up two test plots at two different locations. At each location two 0.2 ha plots were set up, one with low yields and the other with high to represent a 2-cut season system and a 1-cut season system, respectively, at two locations. One location used equipment typically available to small-scale farmers while the other used more powerful equipment typically available in larger farming operations. The experiments used round balers that matched up with the size of the rest of the equipment used. Time was recorded for cutting, raking, and baling operations as well as the size of bale, density of the bale, and the moisture content. They found that on a per Mg basis the total time required to mow, rake, and bale high-yields of switchgrass was considerably lower than for the low-yields.

Mapemba and Epplin, using Tembo's model and the harvest unit size described by Thorsell, *et al.*, studied the use of Conservation Reserve Program (CRP) land in Oklahoma, Kansas, and Texas to produce feedstock for the biorefinery. Tembo, *et al.* created a model that attempts to estimate the optimal number of harvest units that are described in Thorsell, *et al.* as ten laborers, nine tractors, three mowers, three rakes, three balers, and one baler transporter. Tembo's model estimated number of harvester units based on the window of harvest and the number of field days (number of days that field work could be conducted) subject to the tons of biomass needed to operate a specific size gasification-fermentation biorefinery. CRP has constraints on the use of the land enrolled in the program set by The Farm Security and Rural Investment Act of 2002: (i) the land could only be harvested once every three years; (ii) the harvesting of forage would be only open for a 120 day period starting July 2. Mapemba and Epplin assumed an unrestricted harvest season on the CRP grass land and compared it to the 120 day restriction. A drawback to using CRP grassland is that if the land was used to produce forage then the government payment to the landowner would be cut by twenty-five percent. Mapemba and Epplin did not address how landowners would be compensated for this loss. Mapemba and Epplin also did not show a cost of producing or maintaining feedstock.

Cost of Operations

Soldatos, *et al.* point out that perennial energy crops tend to have high costs in the establishment year, with lower annual costs the remainder of the productive life. Soldatos, *et al.* studied different ways to calculate cost for perennial energy crops by estimating the individual year cost, a typical year's cost once the crop reaches maturity, or the overall approach is to estimate the average cost over the entire life of the crop. They point out that the first approach results are not useful and are difficult to use for comparison between plantations, the second approach does not take into account the establishment year, however the third approach includes the initial investment cost and the time value of money and is able to compare directly to different crops.

Several production cost studies exist showing a range from $22/dry Mg ($20/dry ton) to more than $110/dry Mg ($100/dry ton) depending on type of production practices, different kinds of biomass, and expected yields. Comparing production of the many different studies is difficult due to the fact that assumptions such as yields, input levels, and expected prices vary between studies explain some but not all differences. The rest of the variation can be explained by the differences in the framework and methodology used to estimate the cost of production (Walsh).

Lowenberg-Deboer and Cherney estimate that the cost to produce switchgrass is $37/Mg in Indiana however this does not take into account the cost of land, labor, and transportation. In Virginia, Cundiff and Harris estimate production cost to range from $51-$60/Mg. Cundiff, *et al.* estimate this cost due to the assumptions that cropland can be rented for $49/ha, produce 9 dry Mg/ha, and use conventional farming operation and economies of size to spread machinery cost.

Soldatos, *et al.* used BEE (Biomass Economic Evaluation http://www.bee.aua.gr) to estimate the cost of producing *Arundo donax* L. (Giant Reed) and *Miscanthus x gigantheus* (Giant Miscanthus). Based on the third approach that Soldatos, *et al.* explained, the total cost of growing and harvesting Giant Reed is 1,198 per cultivated ha (€) or 76.78 per dry ton (€) while the total cost of growing and harvesting Giant Miscanthus is 1,197 per cultivated ha (€) or 91.06 per dry ton (€). The cost of Giant Reed and Giant Miscanthus reflect the cost of planting, irrigation, fertilization, weed control, harvesting, other operations, land, and overhead. Strauss and Grado estimated total cost to produce, harvest, and transport cost to be $39/Mg (oven dried).

Tembo, *et al.* note that many problems with previous studies on the harvest and transportation cost is that harvest windows, storage location, transportation, and storage losses are fundamentally overlooked. Since their study, several different articles have looked at the cost of transporting LBC to an ethanol plant, all assuming that the biomass would be trucked to the plant or storage facility. The differences between each study were the size of the truck and trailer combination and the distance from pickup to delivery. Cost ranged between $5.50 - $12/dry Mg ($6.05 - $13.20/ton), (Walsh) and $8.80/Mg ($9.68/ton) (Epplin). Thorsell, *et al.*, Walsh, and Epplin have looked at estimates for harvest windows and transportation. Tembo, *et al.* still leaves storage location and storage losses to be estimated.

III. Data and Methods

Mississippi and Oklahoma production and cost data

Annual dry-matter yields for Alamo switchgrass, eastern gammagrass, and giant miscanthus were obtained from experiment station trials that were planted in June of 2002. The experiment was set up as a randomized complete block with four replications and included a total of six treatments. The treatments consisted of the three species with both one and two harvests per year. Dry matter yields were obtained in 2003, 2004, and 2005. SAS was used to analyze and estimate the production and production cost from Mississippi State and Oklahoma State experimental data sets.

Production costs were computed using a standard enterprise budgeting approach. An establishment and a maintenance and harvest cost budget were generated for each of the three species and each method of harvest.

Production and Cost functions

Given the nature of data and information collected, the estimation production cost by three species and method of harvest is based on the theory of duality between production function and cost function. Production function is estimated using yield (tons per acre) to account for technology change, method of harvest (single or double harvest). The production function can be represented as

$$(1) \qquad y = f(x, t)$$

where x represents method of harvest (single or double) and t is a technology time trend given the input use is constant or invariant across the species and harvest.

To account for variation across observations, species, and method of harvest, the yield estimate from the production function is used in the cost function to estimate production costs. Further, since costs are constant across observations within species, harvest, and year the predicted production per acre is used as an input in the cost function. Hence, the production costs are estimated taking into account variation in the production (from equation 1), species, harvest and year taking advantage of duality theory between cost and production. To estimate the production costs, the cost function can be defined as

$$(2) \qquad C = f(\hat{y},\ species\,dummy,\ harvest\,dummy,\ year)$$

where $\hat{y}$ is the predicted production for the production function defined in equation 1, species dummy represents dummy for the three species, and the harvest dummy represent the single and double harvest.

IV. Results and discussion

To examine the production per acre and production cost by species and method of harvest, equation (1) and (2) are estimated using ordinary regression analysis. The parameter coefficients of the production function and cost function are presented in Table 1. Tables 1-4 display the estimated production per acre and cost associated with producing switchgrass, giant miscanthus, and eastern gammagrass as potential biomass feedstocks in Mississippi and Oklahoma. Tables 1 and 3 represent the yields and costs associated with Mississippi production. Oklahoma yields and costs are shown in Tables 2 and 4. In Tables 1 and 2, the single harvest and double harvest is the number of harvests performed during a single growing season. The actual represents the mean of the yields harvested from the test plots, while the predicted is the estimated yield. The predicted yield was calculated from three years of actual plot yields. This is the yield that is expected to be reached by each species.

Table 1. Mississippi Estimated Yields for Potential Biomass Feedstocks (tons per acre).

	Single Harvest		Double Harvest	
Species	Actual	Predicted	Actual	Predicted
Switchgrass	12.485	12.989	14.971	14.468
Giant Miscanthus	14.465	14.974	16.454	15.945
Eastern Gammagrass	4.755	4.894	8.743	8.396

Table 2. Oklahoma Estimated Yields for Potential Biomass Feedstocks (tons per acre).

	Single Harvest		Double Harvest	
Species	Actual	Predicted	Actual	Predicted
Switchgrass	7.083	7.056	6.883	6.910
Giant Miscanthus	5.533	5.570	5.822	5.784
Eastern Gammagrass	4.244	4.254	4.421	4.411

Tables 3 and 4 represent the cost associated with yields displayed in Table 1 and 2 respectively. The establishment year cost and maintenance and harvest year cost are shown in dollars per acre. The establishment cost is different across species but is the same for both the single and double harvest methods. This cost is only paid in the year that the seed is planted. The following years are only maintenance and harvest years. Since there is no defined stand life length for any of the species, the establishment year's cost was amortized using equal payments over the five, ten, and fifteen year expected life of the stands. After the establishment costs were amortized, the corresponding maintenance and harvest year costs were added to the amortized cost before calculating actual and predicted cost per ton.

Table 3. Cost of Producing Potential Biomass Feedstocks in Mississippi.

		Switchgrass		Giant Miscanthus		Eastern Gammagrass	
		SH	DH	SH	DH	SH	DH
Establishment Cost per acre		286.29	286.29	803.20	803.20	318.87	318.87
Maintenance and Harvest Cost per acre		271.20	301.77	253.02	283.59	267.52	297.78
Cost per ton (EST. Amortized 5 years)	Actual	32.18	28.66	36.30	33.45	139.72	42.54
	Predicted	27.51	26.25	33.74	32.53	71.10	44.06
Cost per ton (EST. Amortized 10 years)	Actual	29.41	26.40	29.55	27.64	126.47	38.83
	Predicted	25.16	24.16	27.47	26.89	64.42	40.13
Cost per ton (EST. Amortized 15 years)	Actual	28.50	25.66	27.35	25.74	122.14	37.62
	Predicted	24.39	23.48	25.42	25.04	62.23	38.85

Table 4. Cost of Producing Potential Biomass Feedstocks in Oklahoma.

		Switchgrass		Giant Miscanthus		Eastern Gammagrass	
		SH	DH	SH	DH	SH	DH
Establishment Cost per acre		123.35	123.35	834.63	834.63	140.15	140.15
Maintenance and Harvest Cost per acre		81.02	118.41	71.59	102.69	63.77	89.70
Cost per ton (EST. Amortized 5 years)	Actual	15.96	22.07	48.90	51.45	23.33	31.18
	Predicted	15.97	20.87	48.44	50.17	26.28	29.82
Cost per ton (EST. Amortized 10 years)	Actual	14.13	20.19	33.23	36.70	22.40	27.55
	Predicted	14.19	19.05	33.23	35.52	19.79	26.42
Cost per ton (EST. Amortized 15 years)	Actual	13.54	19.57	28.11	31.88	21.12	26.36
	Predicted	13.61	18.46	28.26	30.74	18.64	25.31

Conclusions

Based on the results the conclusions drawn from this study is that over all the plots were used in growing switchgrass, giant miscanthus, and eastern gammagrass, switchgrass produced more tons on a per acre basis than the other species in both the single and double harvest seasons in Oklahoma. However in Mississippi, giant miscanthus produced more tons per acre than the other species. In all Mississippi production, a double harvest method produced more tons per acre than a single harvest method. The same was true for Oklahoma except for switchgrass, which actually had decreased yields per acre with a double harvest method. In the establishment year, giant miscanthus held the highest cost per acre in both Mississippi and Oklahoma. The fifteen-year stand life reflects the lowest cost per ton, which can be explained by the simple fact that the longer that the fixed costs of the establishment year can be spread decreases the annual cost. According to the actual cost per ton, the cheapest feedstock to produce in Mississippi is switchgrass with a double harvest method. In Oklahoma, switchgrass under a single harvest method produces the cheapest biomass feedstock per ton. This research shows that in Oklahoma, switchgrass under a single harvest method produces the highest yield and the lowest cost per ton of biomass feedstock. While in Mississippi, the double harvest method of producing giant miscanthus had the highest yields, while the double harvest method of producing switchgrass had the lowest cost per ton of biomass feedstock. Nevertheless further research is needed on the conversion ratio and cost of operating a lignocellulosic biorefinery, before being able to select the most efficient biomass feedstock for the production of ethanol.

References

1. Bransby, D.I., S.E. Sladden, and M. Downing. Yield effects on bale density and time required for commercial harvesting and baling of switchgrass. Proc., Bioenergy '96 – The Seventh National Bioenergy Conference: Partnerships to Develop and Apply Biomass Technologies, September 15-20, 1996, Nashville, Tennessee.

2. Bush, George W., State of the Union Address. http://www.whitehouse.gov/stateoftheunion/2006/ January 31, 2006. (Accessed January 16, 2007.)

3. Cundiff, J.S. and W.L. Harris. Maximizing output-maximizing profits: production of herbaceous biomass for fiber conversion should be a carefully managed equipment-based enterprise. *Resource* 1995;2:8-9

4. Epplin, F.M. Cost to produce and deliver switchgrass biomass to an ethanol-conversion facility in the southern plains of the U.S. *Biomass and Bioenergy* 1996;11(6):459-467.

5. Jarvis, E.E. Biomass Refining: The Future of Ethanol. Initiative for Renewable Energy and the Environment Symposium Presentation. Internet site: http://www1.umn.edu/iree/pdfs/jarvis.pdf, (November 29, 2005)

6. Kenkel, P., R.B. Holcomb. Challenges to Producer Ownership of Ethanol and Biodiesel Production Facilities. Selected Paper prepared for presentation at Southern Agriculture Economics Association meetings, February 4-8, 2006, Orlando, Florida.

7. Lowenberg-DeBoer, J. and J.H. Cherney. Biophysical simulation for evaluation new crops: the case of Switchgrass for biomass energy feedstock. *Agricultural Systems* 1989;29:233-246

8. Mapemba, L.D. and F.M. Epplin. Use of Conservation Reserve Program Land for Biorefinery Feedstock Production. Selected Paper prepared for presentation at the American Agricultural Economics Association annual meetings. August 1-4, 2004, Denver, Colorado.

9. Renewable Fuel Association, Internet site: http://www.ethanolrfa.org, (Accessed March 3, 2006)

10. Soldatos P.G., V. Lychnaras, D. Asimakis, and M. Christou. BEE – Biomass Economic Evaluation: a model for the economic analysis of evergy crops production. May10-14, 2004 "2nd World Conference and Technology Exhibition on

Biomass for Energy, Industry and Climate Protection.” Agricultural University of Athens (AUA), Laboratory of Agribusiness Management.

11. Strauss, C.H. and S.C. Grado. Input-output analysis of energy requirements for short rotation, intensive culture, woody biomass. *Solar Energy* 1992;48(1):45-51

12. Tembo, G., F.M. Epplin, and R.L. Huhnke. Integrative Investment Appraisal of a Lignocellulosic Biomass-to-Ethanol Industry. *Journal of Agricultural and Resource Economics* 2003;28(3):611-633

13. Thorsell, S., F.M. Epplin, R.L. Huhnke, and C.M. Taliaferro. Economics of a coordinated biorefinery feedstock harvest system: lignocellulosic biomass harvest cost. *Biomass and Bioenergy* 2004;27:327-337.

14. U.S. Department of Energy, Internet site: http://www.eere.energy.gov/cleancities/blends/ethanol.html, (Accessed March 3, 2006)

15. U.S. Department of Energy, Energy Information Administration, Internet site: http://www.eia.doe.gov/emeu/cabs/topworldtables3_4.html, (Accessed June 1, 2006)

16. Walsh, M.E. U.S. bioenergy crop economic analyses: status and needs. Biomass and Bioenergy 1998;14(4):341-350