ECONOMIC ANALYSIS OF ENERGY CROP PRODUCTION IN THE U.S.-- LOCATION, QUANTITIES, PRICE AND IMPACTS ON TRADITIONAL AGRICULTURAL CROPS

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ABSTRACT

POLYSYS is used to estimate U.S. locations where, for any given energy crop price, energy crop production can be economically competitive with conventional crops. POLYSYS is a multi-crop, multi-sector agricultural model developed and maintained by the University of Tennessee and used by the USDA-Economic Research Service. It includes 305 agricultural statistical districts (ASD) which can be aggregated to provide state, regional, and national information. POLYSYS is being modified to include switchgrass, hybrid poplar, and willow on all land suitable for their production. This paper summarizes the preliminary national level results of the POLYSYS analysis for selected energy crop prices for the year 2007 and presents the corresponding maps (for the same prices) of energy crop production locations by ASD. Summarized results include: (1) estimates of energy crop hectares (acres) and quantities (dry Mg, dry tons), (2) identification of traditional crops allocated to energy crop production and calculation of changes in their prices and hectares (acres) of production, and (3) changes in total net farm returns for traditional agricultural crops. The information is useful for identifying areas of the U.S. where large quantities of lowest cost energy crops can most likely be produced.

Keywords: energy crops, biomass economics, agricultural economics

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INTRODUCTION

While many biomass feedstocks (e.g., forest residues, agricultural residues, municipal solid waste, energy crops) can potentially be used to produce liquid fuels, electricity, and heat, the development of a biomass industry capable of providing substantial quantities of energy will require the large-scale production of dedicated energy crops. This situation raises many economic and environmental questions. Among the economic questions of interest are: (1) how many acres could be available for energy crops production, (2) what prices are needed to entice farmers to plant energy crops, (3) where is energy crops production most competitive with traditional crops, (4) what effects will large-scale production of energy crops have on the prices and quantities of traditional agricultural crops, (5) how will production of energy crops affect net farm returns, and (6) how might agricultural and energy policies affect energy crops production. To help evaluate these questions, the U.S. Department of Agriculture (USDA) and the U.S. Department of Energy (DOE) are collaborating to modify an agricultural sector model (POLYSYS) to include energy crops (switchgrass, hybrid poplar, willow).

ANALYTICAL APPROACH

Model Description. POLYSYS was developed by, and is maintained by, the University of Tennessee Agricultural Policy Analysis Center (Ray et al, 1997). It is used by the USDA Economic Research Service to conduct policy analysis. POLYSYS contains the major agricultural crops (corn, wheat, soybeans, cotton, rice, grain sorghum, barley, oats) and livestock (swine, beef, dairy, poultry, sheep), and has been modified to include alfalfa and other hay crops as well as energy crops. The model also includes food, feed, industrial, and export demand functions for agricultural products. POLYSYS is aggregated into 305 Agricultural Statistical Districts (typically containing five to eight counties) which can be combined to provide local, state, regional, and national level results.

POLYSYS allocates land to each crop based on a comparison of its relative profitability (i.e., price * yield - production costs). The introduction of energy crops into agriculture results in the shifting of acres from traditional crop production, thus altering the prices and quantities of these crops. These changes are estimated using feedback mechanisms and repeated iterations until equilibrium prices and quantities are achieved. Because the model is anchored to the USDA baseline[4] (to the year 2007), estimated changes in the prices, yields, acres, quantities, and net income of traditional agricultural crops are calculated as deviations from the baseline.

[4] The USDA baseline does not include hay crops. The Food and Agricultural Policy Research Institute Baseline was used for alfalfa and other hay crops.

Incorporation of Energy Crops into POLYSYS. The land base in the model is currently limited to hectares (acres) that are classified as cropland and planted to the eight major crops (106 million hectares, 261 million acres), alfalfa (11 million hectares, 27.3 million acres), and other hay crops (13.5 million hectares, 33.4 million acres). Of the total land contained in the model (130.2 million hectares, 321.7 million acres), 104 million hectares (257 million acres) are considered suitable for energy crop production and include hectares in the eastern half (i.e., land east of central North Dakota, South Dakota, Kansas, Nebraska, Oklahoma, and Texas) of the United States (for all three energy crops) and the Pacific Northwest (for poplar). Hectares that are idled (either in CRP or for other reasons) have not yet been incorporated into the model at the time that this paper was written.

Because energy crops require multi-year rotations, POLYSYS utilizes a net present value approach to compare the relative profitability of energy crops and traditional agricultural crops. Additionally, the model incorporates into the decision function, the expected price changes of traditional crops resulting from large-scale energy crop production. POLYSYS also contains constraints that limit the acreage that a crop can gain or lose in any given year, and it assumes that once land is allocated to an energy crop, the land remains in energy crop production for the full rotation length of the crop.

To ensure consistency in estimating the cost of producing energy crops and traditional agricultural crops, the same budget generator system was used when feasible. For traditional crops and for site preparation and fertilizer and herbicide application for energy crops, the ABS budget system was used (the budget generator model associated with POLYSYS) (Slinsky et al, 1996). Energy crop harvest costs were estimated by BIOCOST (ORNL energy crop production cost model) (Walsh and Becker, 1996). Production cost estimates include all variable cash costs (seed, cuttings, fertilizer, chemicals, fuels, etc.), labor costs, machinery costs (storage, insurance, depreciation, opportunity cost of ownership), and interest costs. A workshop, attended by energy crop experts from DOE and USDA, reviewed the energy crop management practices used in the budget generator models. Energy crop yields and geographic location of lands suitable for energy crop production were based on data contained in the ORECCL database (Graham et al, 1996), and were also reviewed by the workshop participants.

RESULTS

POLYSYS provides estimates for each year between 1998 and 2007—for this paper we present results for just the year 2007. Additionally, POLYSYS has been used to run several energy crop price scenarios--we include summary results for two scenarios only (Table 1). The prices presented are farmgate prices (i.e., the price that must be paid to the producer). Transportation costs from the site of production to a storage or end user facility are not included. Storage costs and losses are also not included. It should be noted that the presented results are preliminary; all model modifications have not yet been completed and review of the analyses by USDA and DOE are still ongoing.

Table 1. Energy Crop Price Scenarios (Year 2007)

Scenario 1			
	Switchgrass	Poplar	Willow
Price ($/dry Mg)	38.50	42.23	40.73
Price ($/dry ton)	35.00	38.39	37.03
Price ($/GJ)	2.14	2.14	2.14
Price ($/MBTU)	2.26	2.26	2.26
Scenario 2			
	Switchgrass	Poplar	Willow
Price ($/dry Mg)	55.00	60.32	58.19
Price ($/dry ton)	50.00	54.84	52.90
Price ($/GJ)	3.06	3.06	3.06
Price ($/MBTU)	3.23	3.23	3.23

The analysis assumes the same price (on an energy content basis) for all three energy crops. In the model, energy crops not only compete with traditional crops, they compete with each other in areas where more than one energy crop can be grown—the land is allocated to the crop that is most profitable. Table 2 presents the hectares (acres) of energy crops that could economically compete with traditional crops under the two scenarios described above.

For each energy crop price scenario presented, switchgrass is more profitable than poplar and willow given the production cost and yield assumptions incorporated into the analysis. Thus, most energy crop hectares are allocated to switchgrass rather than short rotation wood crops. At a price of $38.50/dry Mg ($35.00/dry ton), an estimated 3.91 million hectares (9.66 million acres) of switchgrass could be produced at a profit at least as great as for traditional agricultural crops produced on the same land. Total production is about 45 million dry Mg annually (50 million dry tons). At an equivalent energy price ($42.23/dry Mg and $38.39/dry ton for poplar; $40.73/dry Mg and $37.03/dry ton for willow), 24,000 hectares (60,000 acres) of poplar and 32,000 hectares (80,000 acres) of willow could be grown resulting in an additional annual production of 627,000 dry Mg (690,000 dry tons) of biomass. At a price of $55.00/dry Mg ($50.00/dry ton), an estimated 7 million hectares (17.3 million acres) of switchgrass can be grown resulting in an annual production of 79 million dry Mg (87 million dry tons) of biomass. At an equivalent energy price ($60.32/dry Mg and $54.84/dry ton for poplar; $58.19/dry Mg and $52.90/dry ton for willow), 32,000 hectares (80,000 acres) of poplar and 77,000 hectares (190,000 acres) of willow could be grown resulting in an additional annual production of 1.2 million dry Mg (1.3 million dry tons) of biomass.

Table 2. Impacts of Energy Crops on Land Allocation (Year 2007)—Preliminary Results

	Hectares (million)		Acres (million)	
	Scenario 1	Scenario 2	Scenario 1	Scenario 2
Corn	-0.085	-0.733	-0.21	-1.81
Sorghum	-0.178	-0.227	-0.44	-0.56
Oats	-0.328	-0.324	-0.81	-0.80
Barley	-0.154	-0.162	-0.38	-0.40
Wheat	-0.672	-1.862	-1.66	-4.60
Soybeans	-0.109	-0.810	-0.27	-2.00
Cotton	-0.117	-0.271	-0.29	-0.67
Rice	-0.016	-0.028	-0.04	-0.07
Alfalfa	-0.255	-0.324	-0.63	-0.80
Other Hay	-2.044	-2.385	-5.05	-5.89
Switchgrass	+3.91	+7.01	+9.66	+17.34
Poplar	+0.024	+0.032	+0.06	+0.08
Willow	+0.032	+0.077	+0.08	+0.19

Table 2 also summarizes the hectares (acres) of traditional crops that could potentially be shifted from traditional crop production to energy crop production. Energy crops are most competitive with wheat and non-alfalfa hay, although some hectares of all major crops could potentially be allocated to energy crops.

Figures 1 and 2 show the location of switchgrass production by agricultural statistical district (ASD) for the two price scenarios. As energy crop prices increase, a greater number of ASDs enter into the solution set and a larger number of hectares is planted to energy crops in each ASD. The analysis indicates that switchgrass can be produced in substantial quantities at lowest price in the Lake States, North Plains, South Plains, and Southeast. Parts of the Midwest and Northeast enter the solution as switchgrass price increases. Short rotation woody crop production occurs primarily in Tennessee, Louisiana, Minnesota, and Oregon for poplar, and the Northeast and Lake States for willow.

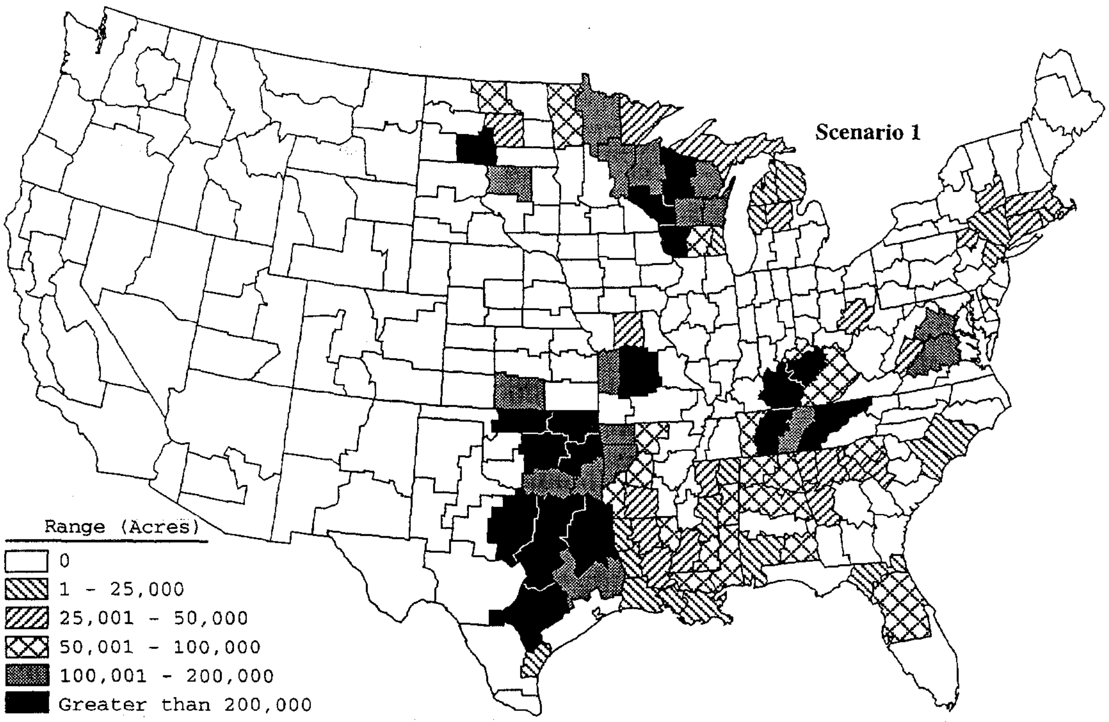

Figure 1. Acreage Planted to Switchgrass by Agricultural Statistical District, Scenario 1 (Year 2007)—Preliminary Results

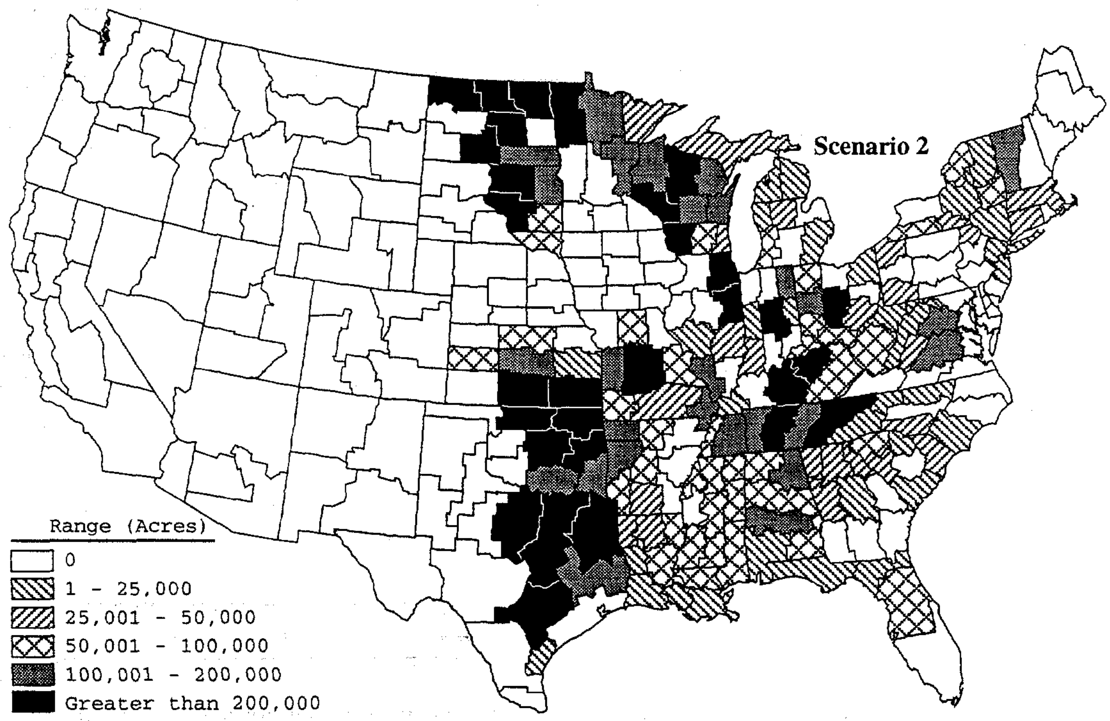

Figure 2. Acreage Planted to Switchgrass by Agricultural Statistical District, Scenario 2 (Year 2007)—Preliminary Results

As increasing acres of traditional crops are allocated to energy crop production, quantities of traditional crops decrease. This results in a change in the price of traditional crops. Table 3 presents the estimated change in price of traditional crops for each of the two energy crop price scenarios. Limitations in the model prevent an estimate of changes in alfalfa and other hay prices. Prices of minor feed grains such as grain sorghum, oats, and barley show the greatest increase, but wheat, corn, and soybean prices also show price increases of more than 5 percent above the baseline estimate for the higher energy crop price scenario (scenario 2).

Changes in crop prices also result in changes in net farm returns. Table 4 shows the estimated changes in total and per crop net farm returns for the major agricultural crops resulting from large-scale energy crop production. Increases in net farm returns are greatest for corn, soybeans, and wheat because of the large quantities of these crops produced in the U.S. Additional returns will be earned from the production of energy crops. Due to limitations in the model, net return effects for hay crops and the livestock sector can not be estimated but it is likely that net returns will increase for hay producers and decrease for livestock producers as a result of higher feed prices.

Table 3. Changes in Prices of Traditional Agricultural Crops as a Result of Energy Crop Production (Year 2007)—Preliminary Results

Crop		Change in Price from Baseline ($/unit)		Percent Change in Price from Baseline	
	Baseline Price	Scenario 1	Scenario 2	Scenario 1	Scenario 2
Corn	$3.10/bu	+ 0.02	+ 0.15	+ 0.6	+ 4.8
Sorghum	$2.90/bu	+ 0.20	+ 0.35	+ 6.9	+ 12.1
Oats	$1.85/bu	+ 0.36	+ 0.45	+ 19.5	+ 24.3
Barley	$2.80/bu	+ 0.19	+ 0.30	+ 6.8	+ 10.7
Wheat	$4.45/bu	+ 0.14	+ 0.46	+ 3.1	+ 10.3
Soybeans	$7.25/bu	+ 0.05	+ 0.40	+ 0.7	+ 5.5
Cotton	$0.65/lb	+ 0.00	+ 0.01	+ 0.0	+ 1.5
Rice	$12.14/cwt	+ 0.25	+ 0.51	+ 2.1	+ 4.2

Table 4. Changes in Net Farm Returns of Traditional Agricultural Crops as a Result of Energy Crop Production (Year 2007)—Preliminary Results

Crop		Change in Net Returns from Baseline (million $)		Percent Change in Net Returns from Baseline	
	Baseline Net Returns (million $)	Scenario 1	Scenario 2	Scenario 1	Scenario 2
Corn	22,474	+ 154	+1,324	+ 0.69	+ 5.89
Sorghum	952	+ 134	+ 214	+ 14.01	+ 22.48
Oats	18	+ 64	+ 78	+ 350.63	+ 427.24
Barley	683	+ 58	+ 102	+ 8.50	+ 14.95
Wheat	6,199	+ 318	+ 892	+ 5.13	+ 14.38
Soybeans	15,301	+ 117	+ 834	+ 0.76	+ 5.45
Cotton	3,302	+ 4	- 15	+ 0.12	-0.45
Rice	1,663	+ 29	+ 68	+ 1.76	+ 4.07
TOTAL	50,593	+ 878	+ 3,496	+ 1.74	+ 6.91

SUMMARY

The POLYSYS model has been used to estimate selected economic impacts on the U.S. agricultural sector that might result from the large-scale production of dedicated energy crops. Analysis indicates that at farmgate prices of $55/dry Mg ($50/dry ton) of switchgrass ($60.32/dry Mg for poplar and $58.19/dry Mg willow), 80 million dry Mg (88 million dry tons) of biomass could potentially be produced annually at profit at least as a great as could be earned using the land to produce traditional agricultural crops. Production would occur in most regions of the U.S. where the land is physically suitable for the production of energy crops. Land currently in the production of all major agricultural commodities could shift to energy crop production with the greatest shifts being from non-alfalfa hay and wheat. As a result of changes in land allocation among the crops, crop prices increase as does net farm returns.

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