Biofuel Boom, Aquifer Doom?

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Introduction

The expansion of the biofuels industry is having a historic impact on the production of corn and other grains. As corn is among the most input-intensive crops, this extra production has raised concerns about environmental impacts and pressures on water resources in particular. While water quality has been a longstanding concern in the cornbelt, much of the new production is in nontraditional corn regions including the southeast, the High Plains, and the western states. In these areas, there is mounting concern over depletion of already stressed water supplies.

In the High Plains, the chief water source is the Ogallala aquifer, one of the largest water resources in the world that underlies eight states from South Dakota to Texas. The Ogallala has enabled many agricultural industries, such as irrigated crops, cattle feeding, and meat processing, to establish themselves in areas that would not be possible otherwise. A consequence is that the economy of this region has become dependent on groundwater availability. Continued overdrafts of the aquifer have caused a long-term drop in water levels and some areas have now reached effective depletion.

This paper seeks to estimate the impact of the emerging biofuels sector on groundwater consumption and cropping patterns in the Kansas portion of the High Plains Aquifer. The economy of this region is particularly dependent on water and irrigated crops, with more than 3 million head of feeder cattle and irrigated crop revenues exceeding $600 million annually. Sheridan County, in northwestern Kansas, has been selected as a representative case study region. The county has intermediate levels of water supplies remaining compared to other counties in western Kansas. Like the region as a whole, a significant share of pre-development supplies has already been consumed. Cropping patterns in Sheridan County are typical of the region, with most irrigated acreage being planted to corn and with dominant nonirrigated rotations of wheat-fallow and wheat-sorghum-fallow.

A Positive Mathematical Programming (PMP) model (Howitt, 1995) was developed and calibrated to land- and water-use data in Sheridan County for a base period of 1999-2003. The PMP approach produces a constrained nonlinear optimization model that mimics the land- and water- allocation decision facing producers each year. The choice variables in the model are the acreages planted to each of the major crops. Water use can then be calculated by multiplying the irrigated crop acreages by crop-specific water requirements. The PMP calibration procedure ensures that the model solutions fall within a small tolerance of the base period observations.

Once calibrated, the models were executed to simulate the impacts of the emerging energy demand for crops. The models were run under increased crop prices that reflect the escalating prices observed in 2006 and after.

We found that using base prices the amount of nonirrigated corn will exceed that of irrigated corn. Additionally, by year 60 the amount of alfalfa will effectively go to zero. Nonirrigated wheat and sorghum will remain constant while irrigated wheat and soybeans will lose significant acres. When using the current prices that reflect the biofuel effect nonirrigated corn will rapidly exceed irrigated corn and nonirrigated wheat to become the largest crop grown. Irrigated wheat, soybeans, and alfalfa will effectively go to zero within the first few years. Finally, nonirrigated wheat and sorghum will again stay constant. Although all prices are substantially higher in the biofuels scenario, corn prices increase the most, and corn acreage essentially “crowds out” the other crops over time. As corn is the most water-intensive crop, these changes in production exacerbate the aquifer depletion problem.

This remainder of this paper is organized as follows. The next secion briefly reviews the literature related to our methods and procedures. Next, the methods and procedures used in the current study are presented, followed by a description of the base data to which the model is calibrated. The model results are reported, and the final section concludes and discusses further research needs.

Brief Literature Review

There are several papers that have significantly shaped our research. Schaible (1997) incorporated a multi-output and normalized restricted-equilibrium model for field crops and water demand. The first stage of the model uses restricted-profit functions to measure output when the market is in disequilibrium. The second stage takes the observed equilibrium costs and substitutes them into the implicit economic cost functions to make the long-run normalized restricted-equilibrium model. Finally, the third stage uses the Takayama and Judge's Reducibility Theorem to test the reliability of estimated values to the actual values observed. Schaible applied this model to the Pacific Northwest and found that; if producers are allowed to substitute groundwater for surface water they will immediately do so. This implies that the price of water must be set significantly higher to preserve a given amount of surface water when groundwater use is restricted. Another implication is that government restrictions in ground water consumption decrease producer welfare.

Vaux and Howitt (1984) analyzed the economic potential of interregional water trade. The model that the authors employ is similar to that of Takayama and Judge's model, but they added supply and demand functions for each region and curvilinear demand functions. The model was applied to water regions in California. The authors found that when scarcity of water was increased the marginal price increased (ceteris paribus), implying there are substantial grains from interregional water transfers and market solutions.

Provencher and Burt (1994) modified modified the ‘policy iteration approach’ of Howard (1960) by creating two stochastic modeling concepts for large scale water policy that avoid the “curse of dimensionality.” First, they proposed using Monte Carlo simulations for the right hand side of the equation instead of using linear equations. Second, they applied a Taylor series approximation method to Howard’s equation. After applying these two alterations to Howard’s model the authors concluded that the Taylor series approximation method showed the most potential because it is easy to program and can solve the equation in one shot. The Monte Carlo simulations are also useful because the underlying equations can be approximated to any subjective level of precision.

Finally, the Bernardo et al. (1993a, b) provided several insights for constructing regional water policy models. First, they suggest that the researcher must be able to break up the area into well defined, relatively homogeneous sub regions (Sheridan county for our example). Secondly, they point out that regional ground water modeling should include the following three ingredients: a crop production model, a regional mathematical programming model to allot given resources amid the production process in order to maximize profits, and an aquifer simulation model to track the effects on the level of aquifer. This article in particular is important because our process follows this same pattern.

Methods and Procedures

Consider a farmer's land allocation problem, assuming a quadratic cost function:

$$(1)\qquad \begin{aligned} &\max \sum_i p_i y_i x_i - (\alpha_i + \tfrac{1}{2}\gamma_i x_i)x_i \\ &\text{s.t.} \quad \sum_i x_i \le b \end{aligned}$$

Where b is the size of the farm (available land area) and, for crop i, p_i is the output price, y_i is yield per acre, x_i is the land area planted, and (α_i, γ_i) are cost parameters. The Lagrangian function for this problem may be written:

$$(2)\qquad L = \sum_i \left[p_i y_i x_i - \alpha_i x_i - \tfrac{1}{2}\gamma_i x_i^2 \right] + \lambda \left[b - \sum_i x_i \right]$$

where λ is the Lagrange multiplier. The first order necessary conditions to the problem may be written

$$(3)\qquad \frac{\partial L}{\partial x_i} = p_i y_i - \alpha_i - \gamma_i x_i - \lambda = 0, \quad \forall i$$

$$(4)\qquad \frac{\partial L}{\partial \lambda} = b - \sum_i x_i = 0$$

These conditions may be solved for the optimal solutions, x_i^*, which in turn can be used to compute crop-specific (indirect) profits using the formula:

$$(5)\qquad \pi_i^* = p_i y_i x_i^* - (\alpha_i + \tfrac{1}{2}\gamma_i x_i^*)x_i^*$$

While (1) represents the farmer's true optimization problem, it cannot be replicated on a computer because the cost parameters (α_i, γ_i) are unknown to the researcher. However, estimates of these values can be imputed from observed data. In particular, the researcher does observe the optimal solutions (acreage allocations), x_i^*, as well as the profit earned by the average producer,

π_i^*. The latter can be determined from observed prices, yields, and production costs. Let ω_i denote the observed production costs on crop *i*.

Cost function calibration

The first step in determining the cost parameters is to solve the following problem, similar to (1):

$$\begin{aligned} &\max_{\{x_i\}} \sum_i p_i y_i x_i - \omega_i x_i \\ (6) \qquad &\text{s.t.} \quad \sum_i x_i \le b \\ &\qquad x_i \le x_i^* + \varepsilon \end{aligned}$$

where the new constraint is known as a calibration constraint, and ε is a small positive number known as a calibration constant. The Lagrangian for (6) can be written:

$$(7) \qquad L_\varepsilon = \sum_i \left[p_i y_i x_i - \omega_i x_i \right] + \lambda \left[b - \sum_i x_i \right] + \sum_i \mu_i \left[x_i^* + \varepsilon - x_i \right]$$

where μ_i is the Lagrange multiplier on the calibration constraint. The first order necessary conditions to the calibration problem are:

$$(8) \qquad \frac{\partial L_\varepsilon}{\partial x_i} = p_i y_i - \omega_i - \lambda - \mu_i = 0, \quad \forall i$$

$$(9) \qquad \frac{\partial L_\varepsilon}{\partial \lambda} = b - \sum_i x_i = 0$$

$$(10) \qquad \mu_i \left[x_i^* + \varepsilon - x_i \right] = 0$$

Problem (6) is computable because all parameters are known. By construction, its solutions will be within a small tolerance (namely ε) of the observed acreages x_i^*; in the following discussion we will use x_i^* to denote both the observe acreage levels and the solutions to (6). Similarly, π_i^*

will denote both the observed profits and those computed from the solutions to (6):

(11) $\pi_i^* = p_i y_i x_i^* - \omega_i x_i^*$.

Our calibration problem is one of obtaining values for (α_i, γ_i), such that if these values were inserted in problem (1) and it were solved numerically, the optimal solutions would equal x_i^* and the computed profits by crop would equal π_i^*. The information obtained from solving problem (6), namely the values of μ_i, is needed for this calibration process.

By equation (3), if (α_i, γ_i) are set at their correct values then $\alpha_i + \gamma_i x_i^* = p_i y_i - \lambda$. By equation (8), we also know that $p_i y_i - \lambda = \omega_i + \mu_i$. Combining these two relationships, we have:

(12) $\alpha_i + \gamma_i x_i^* = \omega_i + \mu_i$.

By equations (5) and (11), if (α_i, γ_i) are set at their correct values then $p_i y_i x_i^* - (\alpha_i + \frac{1}{2}\gamma_i x_i^*)x_i^*$ $= p_i y_i x_i^* - \omega_i x_i^*$. This equation reduces to:

(13) $\alpha_i + \frac{1}{2}\gamma_i x_i^* = \omega_i$.

Equations (12) and (13) are the system of two equations which uniquely determine the two unknowns (α_i, γ_i), given the observed data (x_i^*, ω_i) and the computed multiplier μ_i. This system can be solved explicitly. Subtracting (13) from (12) gives

(14) $\frac{1}{2}\gamma_i x_i^* = \mu_i$

Solving for γ_i,

(15) $\gamma_i = 2\mu_i / x_i^*$.

Substituting (15) into (13) yields, $\alpha_i + \mu_i = \omega_i$, which can be solved for α_i as:

$$\alpha_i = \omega_i - \mu_i . \tag{16}$$

Dynamic Simulations

To simulate water allocation decisions over time, a dynamically updated water constraint was appended to the calibrated model. During each year of the simulation ($t = 1, \ldots, 60$), the planted acreage each crop i in year t, x_{it}, is predicted by solving the following problem:

$$\begin{aligned} &\max \sum_i p_i y_i x_{it} - (\alpha_i + \tfrac{1}{2}\gamma_i x_{it}) x_{it} \\ &\text{s.t.} \quad \sum_i x_{it} \le b \\ &\qquad \sum_i w_i x_{it} \le W_t \end{aligned} \tag{17}$$

where w_i is the water requirement for crop i ($w_i = 0$ for nonirrigated crops), and W_t is the maximum feasible withdrawal (in acre feet) in the aquifer in year t given current aquifer levels. W_t is determined by the pumping capacity of the average well in the county, which in turn depends on current saturated thickness (feet), ST_t, and the hydraulic conductivity of the aquifer, K (Hecox et al., 200?). From cross sectional data on well capacities and aquifer characteristics, Golden, Peterson, and O'Brien (2008) estimated the following relationship:

$$GPM_t = -488.93 + 3.68K + 8.75ST_t + .05ST_t^2 . \tag{18}$$

where GPM is the pumping capacity in gallons/minute. The maximum feasible withdrawal, W_t, is then proportional to GPM_t, with the coefficient accounting for the number of active wells in the county, an assumed pumping duration (pumping days per year), and the conversion of units from gallons to acre feet.

Saturated thickness for the following year is updated by the mass balance identity (Gisser and Sanchez, 1980):

$$ST_{t+1} = ST_t + \frac{R}{S} - \frac{W_t}{S \cdot A} \tag{19}$$

where R is the recharge rate in feet, S is the specific yield of the aquifer, and A is the land area overlying the aquifer. Equation (19) presumes that the water-use constraint in (17) is binding so that water use equals total feasible withdrawals every year. If this is not the case, the model enters actual water use in equation (19) instead of W_t.

Data

Data for this project were obtained from several sources. First, the baseline prices, yields, and acres grown were taken from the National Agricultural Statistic Service (NASS) database. To obtain these values we used an average estimate from 1999-2003 for our baseline simulation. An alternative simulation was run for prices reflecting increased demand for grains following the expansion of biofuel production in 2006. These prices were taken from current Kansas State University crop enterprise budgets. Revenue per acre was calculated for each crop revenue as the product of price and yield. These parameters are shown in Table 1.

Production costs were also obtained from Kansas State University Extension budgets. Production costs were subdivided into three categories: nonirrigation cost, irrigation costs, and harvest costs. The costs per acre estimates were derived by adding these three costs together. These parameters are also shown in Table 1.

Finally, hydrological data were drawn from the Kansas Geological Survey. Their data base and previous research provided information on aquifer level (saturated thickness), lift, recharge rate, well count, area above the aquifer, etc. These parameters are shown in Table 2.

Results

After running our model we obtained results for a "no change" in prices over the 60-year planning horizon (assuming average prices from 1999-2003) and for current prices. We were then able to compare these results to each other and to base crop acres (1999-2003). In this section we will make individual observations about each scenario's result, compare the results to each other, and then make overall observations about the model.

First, it is important to discuss the base crop mix shown in Figure 1. There are a few important observations to make from this graph. First, wheat and corn are by far the dominant two crops. On the face level it may seem illogical that wheat would be such a dominant crop because the returns (profit) to wheat are not as high as corn or soybeans (see Table 1). However, wheat is a very popular crop in the area because it is a minimal-input, low maintenance crop that can grow well in marginal land. Additionally, there is a strong cultural tradition of growing wheat in the area. A second observation is that irrigated corn is grown in larger quantities than nonirrigated corn. Again looking at profit margins this makes sense as it is more profit able to grow irrigated than dry land. Finally, it is important to note that irrigated wheat, irrigated soybeans, irrigated alfalfa, and dry land sorghum are the most significant crops in terms of acreage. It is important to keep a mental image of this base crop mix to put the simulated projections in context.

The baseline simulation assuming base prices produced some interesting results. The results for selected simulation years are presented in Table 4. Figure 2 shows the composition of the planted acreage in the final year of simulation, while Figures 3 and 4 depict the trends in nonirrigated and irrigated crops, respectively. There are several notable aspects of these results. First, there is a general phasing out of irrigated crops into nonirrigated crops as water supplies deplete over time. Corn is specifically interesting because in the base period there were 12,834 more acres of irrigated corn than irrigated (Table 4); however, under this simulation nonirrigated corn exceeds irrigated corn acres by year 24. Additionally, by the time the simulation has reached year 60 nonirrigated corn exceeds irrigated corn by 57,223 acres and comprises 33% of the total crop mix, second only to dry land wheat (Table 4, Figures 2 and 3). These changes occur because the amount of available water for irrigation declines over time. Additionally, as the amount of water declines it becomes more costly to pump water for irrigation. These two factors help explain this trend.

Second, it is important to note that the other irrigated crops (soybeans, alfalfa, and wheat) area almost completely phased out as they combine for a total of 4,311 acres by year 60. The gradual decline in these crops can be seen in Figure 4. This trend can also be explained by the above analysis. It is also logical to assume that the some of the acres flowing out of these crops are going into nonirrigated corn, contributing to the steady increases in acreage of that crop.

Finally, both nonirrigated wheat and sorghum stay at the same level as their base period levels (Figure 3). There are several reasons for the constant trend. As mentioned before wheat is a very low-input, low-maintenance crop and carries a cultural factor. Therefore, all of the acres that are "suitable" for wheat production are most likely in use every period. Sorghum is much the same as wheat because it is also a low-maintenance crop. Additionally, many farmers will follow a wheat crop with an immediate sorghum crop because the growing season align such that you can get two crops in a three-year period on the same field (the move to no-till agriculture also plays a factor in this decision). Hence it would seem logical that if dry land wheat acres stay the same so should dry land sorghum.

The second simulation suggests stark changes in cropping patterns will arise from the price effects of biofuels production. The simulated acreages for selected years are in the last four columns of Table 4, while the crop mix at year 60, change in nonirrigated crops, and change in irrigated crops can be seen in Figures 5, 6, and 7, respectively. Here again there are multiple interesting observations. First, dry land corn acre surpass both irrigated corn and dry land wheat, in fact by year 60 it comprises 41% of the total cropped acreage. Additionally, the rate at which nonirrigated corn surpasses irrigated corn is much faster than before as more acres of nonirrigated corn are grown than irrigated corn by year 17. Evidently, the new price regime makes nonirrigated corn a highly attractive alternative on a large number of parcels compared to other nonirrigated crops. While irrigated corn also becomes attractive compared to other irrigated crops, the advantage is not as great in terms of acreage. As further evidence that nonirrigated producers would be drawn to corn, nonirrigated corn actually exceeds nonirrigated wheat by year 45, and by year 60 this gap grows to some 13,273acres. Figure 6 clearly depicts the steady increase of nonirrigated corn and the constant values for nonirrigated wheat and sorghum. As mentioned before we should not be surprised by the constant values for both of these crops.

The second important observation is the rate at which irrigated wheat, alfalfa, and soybeans diminish to zero. Irrigated wheat become statistically zero at year 35, but irrigated soybeans and alfalfa become statistically zero after the first year of simulation. This is interesting because there are multiple price effects and land substitutions occurring at the same time. For example, the current prices are a reflection of the biofuel demand, so we see the price of corn jump by more than the other crops. At the same time this puts a strain on the amount of land available and increases the prices of wheat, sorghum, soybeans, alfalfa, etc. From our simulation model it is clear that the increased prices for corn compete for land against the other crops and outweigh the price increase of soybeans and alfalfa, at least in Sheridan County. Irrigated wheat is a slightly different story as it continues to be part of the crop mix for multiple years; however, it too is eventually phased out. Each of these effects, and the dominance of irrigated corn, can be very clearly seen in Figure 7.

There are also several interesting comparisons between the two simulations. First, both simulations showed that neither dry land wheat nor sorghum increased in acreage. This is important because it shows the strength of the PMP modeling picking up on the marginal land and cultural effects. Had we used a simple optimization tool these two outcomes would have been significantly different. Secondly, both simulations show a decline in irrigated crops and a shift towards nonirrigated (specifically nonirrigated corn) crops over time. This is consistent with the idea that as more irrigation is used more water is required, in turn driving the water level down and the cost to pump up, and finally resulting in less irrigated acres. The large difference between the two simulations is the rate at which this takes place. Finally it is interesting to note the different crop allotments for the last year of simulation (year 60). Under the base price simulation there are two dominant crops, two intermediate crops, and three crops will very small acreages. The current price simulation results in two very dominant crops, two small-er-than-average crops, and almost no production from any other crop type. We would suspect that if we continued out the base price simulation it would have eventually reached the same conclusion as the current price simulation; however, the rate at which the current price simulation displays this result is rather alarming.

In sum, the general phasing out the irrigated crops to nonirrigated crops was an expected result. The current price simulation phased out the irrigated crops more quickly than might be anticipated, but the massive shift to nonirrigated corn helps explain this trend. The PMP process worked well in projecting the effects of the current price and the base year price. As mentioned before, the strength of the model can be observed by the relatively dispersed distribution of crops over time. Conversely, had we used a simple optimization process we would not have seen a distribution, but rater all resources allocated to the single most profitable crop each year.

Conclusion

The goal of this project was to approximate the impact of the budding biofuels sector on groundwater consumption and cropping patterns in the Kansas segment of the High Plains Aquifer. To meet this goal we constructed a land and water use model using the PMP method. For simplicity a representative test county (Sheridan County) was chosen, and data to calibrate the model were acquired from NASS, Kansas State Research and Extension, and the Kansas Geological Survey. The model was run over a sixty year time horizon for two scenarios. The first scenario assumed base prices (1999-2003). The second scenario used prices that portray the biofuel impact.

The results for the two scenarios were attained, analyzed, and displayed in Table 4. There were several clear patterns that emerged in the results. First, in both scenarios the use of irrigated crops eventually began to phase out, with several crops moving to statistically zero (Figures 3-7). Second, nonirrigated crops, specifically wheat and corn, become the dominant crops. While both scenarios showed this trend, they did so at a different rate as the biofuels scenario quickly converted more acres into nonirrigated crops. Third, it is fair to conclude that the rising crop prices from the biofuel boom have an equally adverse effect on the aquifer levels. The high demand for water intensive crops, such as corn, puts an additional strain on the aquifer eventually forcing farmers to switch to nonirrigation crops.

This research has established a starting point board for further research on the subject. In particular this model needs to be extended to estimate the exact effect of changes in cropping systems on the saturated thickness and water consumption levels. This development would allow the researchers to better forecast future policy and structural changes. Additionally, specifying continuous production functions (water-yield response curves) instead of fixed water requirements would add more realism and flexibility to the model in forecasting changes in water-use intensity.

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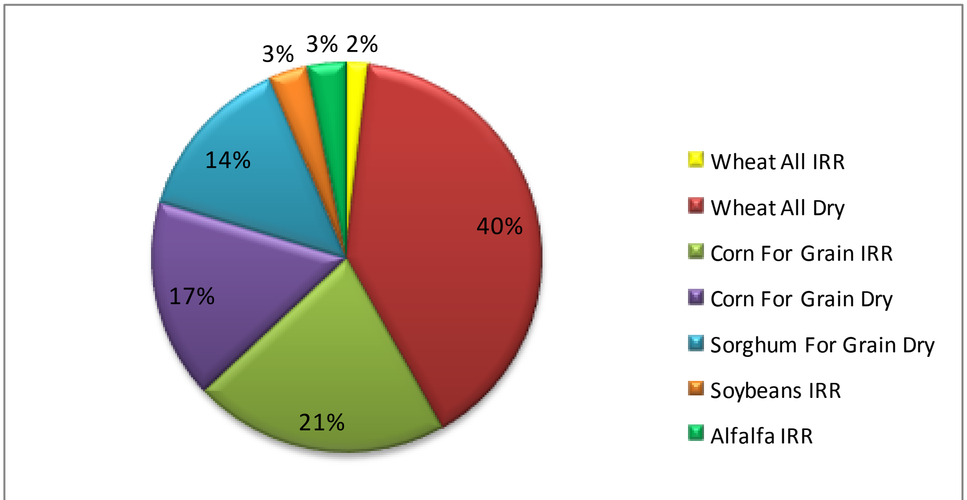

Figure 1. Base Crop Mix

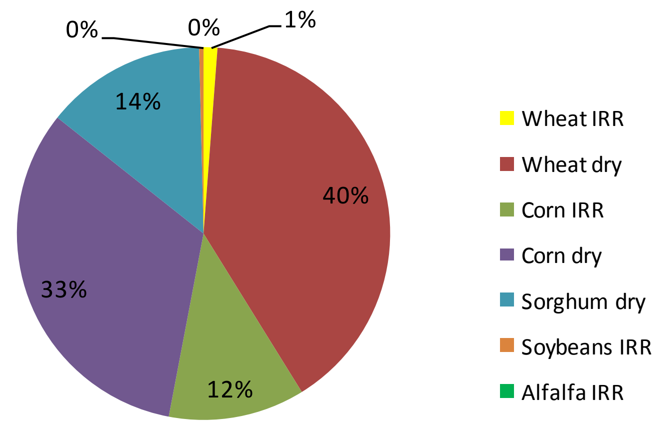

Figure 2. Crop Mix in Year 60, Base Scenario

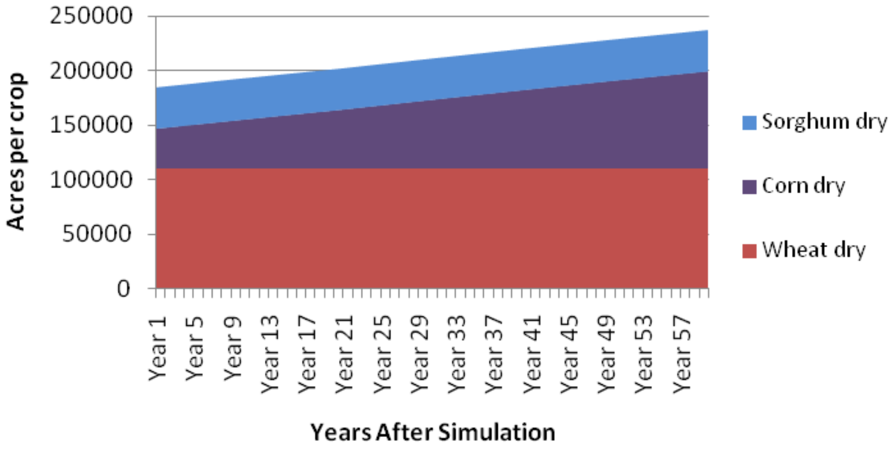

Figure 3. Nonirrigation Crop Acrerages, Base Scenario

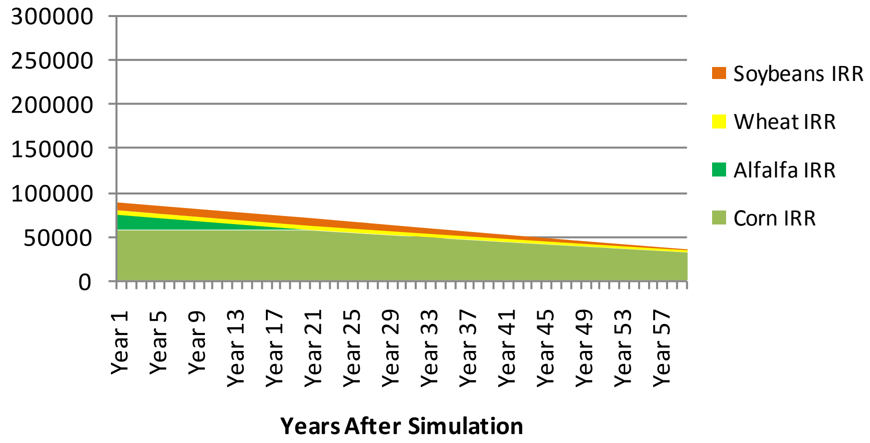

Figure 4. Irrigated Crop Acrerages, Base Scenario

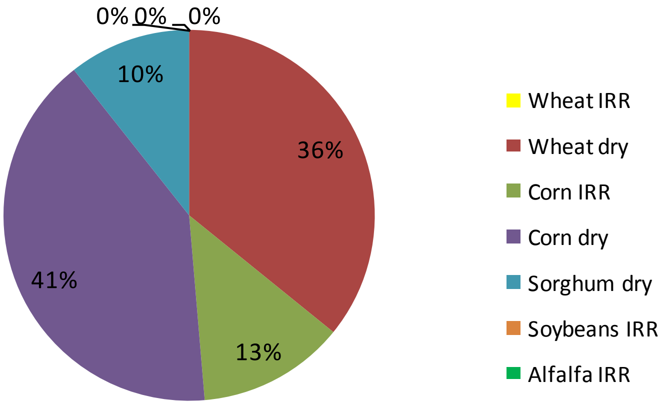

Figure 5. Crop Mix in Year 60, Biofuels Scenario

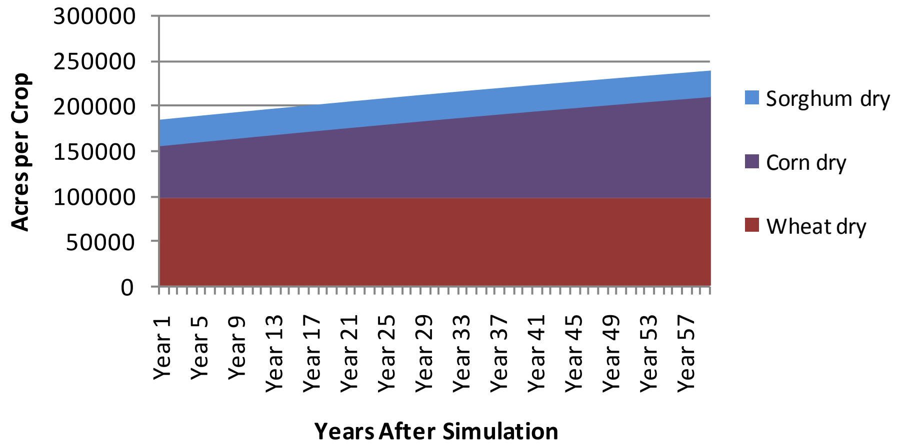

Figure 6. Nonirrigation Crop Acrerages, Biofuels Scenario

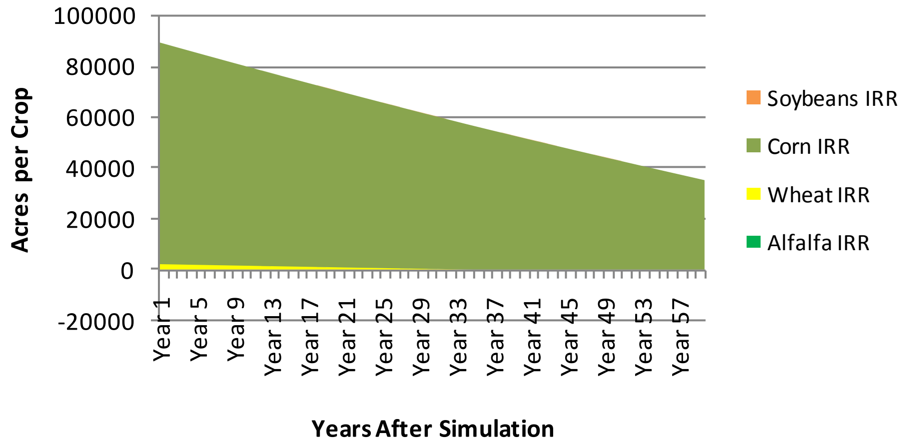

Figure 7. Irrigated Crop Acrerages, Biofuels Scenario

Table 1. Crop production parameters

	Irrigated	Corn		Nonirrigated	Irrigated	Wheat	
Item	Alfalfa	Irrigated	Nonirrigated	Sorghum	Soybean	Irrigated	Nonirrigated
Price							
Base scenario	$83.2/ton	$2.08/bu	$2.08/bu	$1.96/bu	$4.71/bu	$2.8/bu	$2.8/bu
Biofuels scenario	$111.33/ton	$3.97/bu	$3.97/bu	$3.62/bu	$8.31/bu	$5.43/bu	$5.43/bu
Yield	3.3 tons/acre	178.2 bu/acre	58.8 bu/acre	54.92 bu/acre	42.3 bu/acre	52.2 bu/acre	38.6 bu/acre
Water requirement (acre-ft/acre)	1.15	1.06	0.00	0.00	1.01	0.58	0.00
Revenue ($/acre)							
Base scenario	274.56	370.66	122.30	107.64	199.23	146.16	108.08
Biofuels scenario	367.29	707.45	233.44	198.81	351.51	283.45	209.60
Production costs ($/acre)	241.69	270.33	153.19	96.13	139.48	96.05	92.52
Net returns ($/acre)							
Base scenario	32.87	100.33	-30.89	11.51	59.75	50.11	15.56
Biofuels scenario	125.60	437.12	80.25	102.68	212.03	187.39	117.08
Acres planted, base scenario	8794.00	58220.00	45386.00	38197.00	8794.00	5100.00	109542.00
Share of planted cropland (%)	3.21	21.25	16.56	13.94	3.21	1.86	39.97

Source: National Agricultural Statistics Service (NASS): www.nass.usda.gov

Table 2. Hydrologic parameters

Parameter	Symbol	Units	Value
Initial saturated thickness	ST	feet	71.78
Initial pumping lift	H	feet	111.5
Hydraulic conductivity	k	feet/day	68.49
Initial withdrawal limit	W	acre feet/year	30
Annual recharge	R	inches	0.83
Specific yield	s	--	0.1725
Aquifer area	A	acres	566674.0992

Source: Kansas Geological Survey

Table 3. Calibrated Marginal Cost Functions

Crop	Intercept (α)	Slope (γ)
Irrigated alfalfa	241.69	6.368E-09
Irrigated corn	197.79	0.0024919
Nonirrigated corn	153.19	3.0591E-09
Irrigated wheat	46.936	0.019261
Nonirrigated wheat	46.064	0.00084811
Irrigated soybeans	104.75	0.0078996
Nonirrigated sorghum	53.729	0.0022201

Table 4. Simulated Crop Acreages, Selected Years

	Base Scenario				Biofuels Scenario			
Crop	Year 1	Year 20	Year 40	Year 60	Year 1	Year 20	Year 40	Year 60
Irrigated Crops	89,475	72,763	54,189	36,691	89,204	70,481	53,801	35,143
	(32.7)	(26.6)	(19.8)	(13.4)	(32.6)	(25.7)	(19.6)	(12.8)
Alfalfa	17,361	649	0	0	0	0	0	0
	(6.3)	(0.2)	(0.0)	(0.0)	(0.0)	(0.0)	(0.0)	(0.0)
Corn	58,220	58,220	45,144	32,380	87,083	69,590	53,801	35,143
	(21.2)	(21.2)	(16.5)	(11.8)	(31.8)	(25.4)	(19.6)	(12.8)
Soybean	8,794	8,794	4,864	1,028	0	0	0	0
	(3.2)	(3.2)	(1.8)	(0.4)	(0.0)	(0.0)	(0.0)	(0.0)
Wheat	5,100	5,100	4,181	3,284	2,121	891	0	0
	(1.9)	(1.9)	(1.5)	(1.2)	(0.8)	(0.3)	(0.0)	(0.0)
Nonirrigated Crops	184,556	201,268	219,843	237,340	184,829	203,551	220,231	238,891
	(67.3)	(73.4)	(80.2)	(86.6)	(67.4)	(74.3)	(80.4)	(87.2)
Corn	36,819	53,531	72,106	89,603	57,419	76,141	92,821	111,480
	(13.4)	(19.5)	(26.3)	(32.7)	(21.0)	(27.8)	(33.9)	(40.7)
Sorghum	38,197	38,197	38,197	38,197	29,204	29,204	29,204	29,204
	(13.9)	(13.9)	(13.9)	(13.9)	(10.7)	(10.7)	(10.7)	(10.7)
Wheat	109,540	109,540	109,540	109,540	98,206	98,206	98,206	98,207
	(40.0)	(40.0)	(40.0)	(40.0)	(35.8)	(35.8)	(35.8)	(35.8)

Numbers in parentheses are percentages of planted crop acreage