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IMPLICATIONS OF RISING ENERGY COSTS FOR IRRIGATED FARMS IN THE OKLAHOMA PANHANDLE

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As recently as five years ago, research on irrigated crop production in the Oklahoma Panhandle, and surrounding area overlying the central basin of the Ogallala Formation, focused on irrigable acres and regional share of national production as limits to irrigation development. An aggregate analysis was conducted to determine the economic life of the underground water supply for alternative scenarios regarding the rate of development in irrigated crop production (Bekure; Bekure and Eidman). In addition, bio-economic modeling was used to determine the effects of alternative means of regulating water use at the firm level (Mapp; Mapp and Eidman). In these analyses, input and output prices, intensity of production practices and the institutional structure, were assumed constant through time.

Several recent economic analyses have focused on aggregate or regional effects of alternative product and input prices in areas to the south of the central Ogallala (Condra and Lacewell; Lacewell, Condra and Fish). Within the central Ogallala, analysis at the firm level has focused on developing costs and returns for reduced tillage production practices and evaluating the effects of changes in overall energy costs on kilocalories of output (Schwartz; Eidman, Dobbins and Schwartz). This paper examines the impact of rising natural gas prices on the pattern of irrigated crop production, net farm income, and the quantity of water pumped through

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time for representative farms under various sets of assumptions regarding water resource situations, crop prices and tillage practices.

The geographic setting for this analysis is the Oklahoma Panhandle. The area is semi-arid, receiving from 15 to 18 inches of rainfall annually. The existence of large quantities of underground water suitable for irrigation, favorable input and output price relationships, and the profitability of irrigated production have resulted in rapid irrigation development over the past decade. The larger profits from irrigated production are obtained at the expense of greatly increased energy inputs, particularly natural gas. In the three Oklahoma Panhandle counties, 91 percent of the irrigation wells are powered by natural gas (Schwab). Natural gas accounts for about 60 percent of total energy inputs for irrigated production (Table 1). This analysis focuses on the effects of a change in natural gas price rather than an overall rise in the price of energy related inputs.

Recharge of the Ogallala aquifer is small relative to rates of water withdrawal and the static water level is declining steadily (Hart, Hoffman and Goemaat). This analysis accounts for the interaction among rates of water use, water depth, well yield, and pumping costs in determining the optimum organization of production through time.

ALTERNATIVE PRODUCTION ACTIVITIES

Resource requirements, costs and returns are estimated per acre for both conventional and reduced tillage methods of production. Each of the conventional tillage crops, except corn for grain, include three levels of irrigation.[1] The reduced tillage methods of production are based on data

Table 1. Inputs, Production and Net Returns of Production Alternatives

	Irrigation Water	Nitrogen	Phosphate	Herbicide	Insecticide	Diesel	Equip. Lube	Planting Seed: 1st Crop	Planting Seed: 2nd Crop	Labor	Irr. Fuel[a]	Grain Yield: 1st Crop	Grain Yield: 2nd Crop	Grazing Yield	Net Return[b]	NG KCAL/ Total KCAL of Inputs
	ACIN	LBS.	LBS.	LBS.	LBS.	GAL.	QT.	LBS.	LBS.	HRS.	1000 ft^3	LBS.	LBS.	AUM	DOL.	PERCENT
Irrigated Conventional Tillage[d]																
Corn Grain	24	200	50	2.0	1.00	14.37	5.25	20		8.06	16.96	7280			193.51	58.8
Wheat, HI	18	100				10.17	3.99	60		5.67	12.72	3300		.8	112.25	64.5
Wheat, MI	12	75				10.17	2.89	60		4.47	8.48	3000		.7	105.73	59.2
Wheat, LI	8	50				10.17	2.16	60		3.67	5.65	2400		.6	77.43	55.1
Corn Silage, HI	24	200	50	2.0	1.00	29.40	6.16	20		11.07	23.04	40000			80.46	52.8
Corn Silage, MI	16	125	50	2.0	1.00	29.40	4.69	20		9.47	11.31	18750			32.35	47.9
Corn Silage, LI	10	100	50	2.0	1.00	29.40	3.60	20		8.27	7.07	13000			-2.25	38.8
Grain Sorghum, HI	24	150		1.5	1.00	16.17	5.35	10		8.07	16.96	6200		1.4	155.97	62.8
Grain Sorghum, MI	16	120		1.5	1.00	16.17	3.89	10		6.47	11.31	5300		1.2	130.04	56.7
Grain Sorghum, LI	11	100		1.5	1.00	12.77	2.78	7		4.80	7.77	4200		1.0	124.93	52.8
Small Grain Grazing, HI	18	80	40			6.89	3.70	60		4.86	12.72			6.0	-33.24	69.0
Small Grain Grazing, MI	12	60	40			6.89	2.60	60		3.66	8.48			5.0	-36.74	64.3
Small Grain Grazing, LI	8	40	40			6.89	1.87	60		2.86	5.65			3.5	-40.01	59.4
Sudan Hay, HI	24	100				13.17	5.18	10		7.23	16.96	10000			58.63	68.4
Sudan Hay, MI	16	100				13.17	3.71	10		5.63	11.31	6000			-.11	60.5
Sudan Hay, LI	12	80				13.17	2.98	10		4.83	8.48	4800			-13.33	56.7
Soybeans, HI	24	50		1.0		10.86	5.04	90		6.97	16.96	2700			176.30	73.4
Soybeans, MI	20	50		1.0		10.86	4.31	90		6.17	14.13	2400			148.20	71.8
Soybeans, LI	16	50		1.0		10.86	3.57	90		5.37	11.31	2100			120.02	66.6
Irrigated Reduced Tillage																
Corn Grain	24	200	50	2.5	1.00	13.69	5.20	20		7.46	16.96	7560			205.75	59.1
Corn Silage and Rye Graze D.C.	41	200	50	1.5	1.00	27.00	7.85	20	60	14.07	24.03	40000		4.1	24.73	56.9
Wheat-Two Year Rotation[e]	17	100		.5		5.71	3.46	60		6.80	12.01	3390		1.0	120.68	75.2
Wheat and Sorghum D.C.	29	100		1.5	1.00	9.96	.60	60	7	8.45	20.49	3000	4800		258.80	62.6
Three Year Rotation Wheat-Fallow-Sorghum, HI	12	83		1.0	.33	3.83	2.42	20	2.3	3.4	8.48	1098	2067	.79	107.01	65.6
Three Year Rotation Wheat-Fallow-Sorghum, MI	10	80		1.0	.33	3.63	2.01	20	2.3	2.88	6.83	1098	1600	.66	91.05	62.1
Grazed Wheat and Sudan Hay D.C.	36	180		.5		7.94	7.06	60	10	8.73	25.44	7000		5.25	5.87	71.4
Dryland Production																
Wheat	--	60				5.74	.34	45		1.13		990		.35	37.84	--
Grain Sorghum	--					6.83	.41	4		1.33		1100		.75	47.48	--
Small Grain Graze Out	--	30	30			5.09	.31	60		.93				2.4	-1.19	--

[a]Irrigation fuel requirements assume a 950 gallon per minute well and surface distribution system drawing water from a pumping depth of approximately 325 feet.

[b]Net returns represent the residual to land, labor, machinery, overhead, risk and management.

[c]Natural gas kilocalories as a percent of total kilocalories of inputs. Source: Eidman, Dobbins and Schwartz, p. 4.

[d]HI, MI and LI represent high level, moderate level and low level of irrigation, respectively.

[e]The two year wheat rotation alternates conventional and reduced tillage production practices.

compiled by Schwartz and are being used on a limited basis by farmers in the area. All production methods identified can be utilized with minor adaptations in the machinery available on the farm. Thus, the purchase of additional specialized machinery is not necessary. Input requirements, production and net returns for each production activity are presented in Table 1.

PRICES AND NET RETURNS

Two sets of crop prices (low and high) are used in the analysis. The low prices are based on 1976 target prices.[2] Crop prices are not expected to return to these absolute levels. However, the price relatives implied by target prices are based on historic series and provide a lower bound to solutions of the programming model. The high set of prices is based on seasonal average price relationships for the 1969-73 period[3] and provides an upper bound on the programming solutions. Input prices used in the analysis are those prevalent in the study area during early 1976.

The net returns presented in Table 1 represent the residual returns to land, labor, machinery, overhead, risk and management. Residual returns is gross receipts less variable production costs, interest on operating capital and irrigation investment, and depreciation, taxes and insurance on the irrigation system. With the exception of labor costs, this represents the net return to be maximized in the short-run.

REPRESENTATIVE FARM SITUATIONS

Previous studies suggest the economic life of the water supply in the Ogallala Formation differs for different water resource situations (Bekure;

Mapp). Thus, representative farm situations are defined for three water resource situations. The first, a poor water situation, assumes 100 feet of saturated thickness and an irrigation well yield of 400 gallons per minute. The second, a moderate water situation, assumes a saturated thickness of 250 feet and an irrigation well yield of 750 gallons per minute. The third, a good water situation, assumes a saturated thickness of 412 feet, sufficient to produce an irrigation yield of 950 gallons per minute. For each water situation, the representative farm is assumed to contain 1,600 acres of land of which 1,440 acres are cropland, and three irrigation wells equipped with surface distribution systems suitable for clay loam soils of the study area.

The interaction of rate of water use, decline in the water table, and reduction in well yield is accounted for by equations (1) and (2). The decline in static water level during any specified period is given in equation (1):

(1) $D_t = V_t/.2A$

where

D_t = the decline of static water level, period t, in feet,

A = the total number of acres in the farm,

V_t = the number of acre feet of water withdrawn, period t,

.2 = aerial drawdown coefficient.

Associated with the decline in static water level is a decline in irrigation well yield. This relationship may be expressed as

(2) $Q_t = \left[\frac{H_t}{H}\right]^2 Q$

where

Q_t = the well capacity in period t,

H = the original saturated thickness in feet,

H_t = the remaining saturated thickness in period t,

Q = the original well capacity in gallons per minute.

The cost of pumping water during any time period depends upon the initial water situation and prior decisions regarding irrigation intensity. Using equation (1) and (2) pumping costs are adjusted each period to reflect the higher costs associated with reduced well yields and increased lift.

Labor supply on the representative farms is composed of operator labor and one full-time hired man. In addition, the operator can hire up to two additional full-time hired men on an hourly basis. The operator is assumed to borrow operating and investment capital as needed at ten percent and eight percent simple interest, respectively. The model contains restrictions on land, labor, irrigable acres, and the quantity of irrigation water the system can pump by month. In addition to the conventional and reduced tillage cropping activities, a livestock activity for purchasing 400-pound stockers to utilize supplementary grazing is included.

Using a recursive linear programming model, optimum organizations are determined for a series of five-year periods based on well yields and pumping costs at the beginning of the period. That is, an optimum organization is determined for period 1 and is assumed to remain constant for a five-year period. At the end of five years, water use is calculated, drawdown and well yield for the following period are estimated, and pumping costs are adjusted. An optimum organization is re-established and assumed constant for the next five-year period. This procedure continues for 10 five-year periods, or for 50 years. Optimum organizations are developed for representative farms in poor, moderate and good water resource situations for conventional versus reduced and conventional tillage practices, with both low and high crop prices, under conditions of constant and increasing natural gas prices. Only a portion of the results are discussed below.

RESULTS

Rising Natural Gas Price

A series of programming runs were made to determine the potential effects on optimum farm organization, net returns, water use and pumping costs through time of rising natural gas prices.[4] A comparison of the optimal production organizations during periods 1, 5 and 10 under constant and rising natural gas prices for representative farms using only conventional tillage practices is presented in Table 2. As expected, rising natural gas prices increase pumping costs per acre inch and reduce net returns, but the magnitudes of the changes may be surprising. For example, pumping costs rise from $0.99 to $3.24 per acre inch over the 50-year period with constant natural gas price and from $0.99 to $10.75 per acre inch for rising natural gas prices. Net returns decline by 45 percent under constant natural gas prices and by 63 percent under rising natural gas prices.

As pumping costs increase through time, a gradual shift occurs from irrigated to dryland production. One effect of rising natural gas prices is to speed the pace of this adjustment. Under constant natural gas prices, 350 acres of cropland remain in irrigated production in period 10. Under rising natural gas prices, a negative shadow price appears on the irrigation well activities in period 7 indicating an incentive for the producer to disinvest in irrigation facilities. That is, if he were forced to cover both fixed and variable costs in the short run, he would convert to dryland production. Irrigated production remains profitable throughout the 50 year period under constant natural gas prices. The economic life of the water supply is reduced by at least 15 years under rising natural gas prices.

Table 2. Comparison of Optimal Organizations of Production for Conventional vs. Reduced and Conventional Tillage, under Constant and Rising NG Prices, Moderate Water Situation, High Crop Prices

		Conventional						Reduced and Conventional					
		Constant NG Price			Rising NG[a] Price			Constant NG Price			Rising NG Price		
Column		(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
Period		1	5	10	1	5	10	1	5	10	1	5	10
Net Returns	($)	155,361	124,385	85,006	155,361	97,000	57,747	172,071	129,444	86,463	172,071	97,430	57,744
Corn Grain	(Ac.)	220.0	127.6	65.5	220.0	132.4	5.8						
Wheat, HI[b]	(Ac.)	303.3			303.3								
Wheat, MI	(Ac.)		383.8	196.4		397.2		51.6	164.5	77.6	51.6	154.8	
Wheat, LI	(Ac.)								52.2	24.6		49.1	
Soybeans, HI	(Ac.)	196.7			196.7								
Soybeans, LI	(Ac.)		127.6	65.5		132.4							
Grain Sorghum, LI	(Ac.)		42.5	21.8		44.1							
Corn Grain, reduced	(Ac.)							80.5	13.4		80.5	0.5	
Wheat - Two year rotation	(Ac.)							187.5			187.5		
Wheat and Sorghum D.C.	(Ac.)							210.2	192.5	105.9	210.2	210.2	
Three year rotation Wheat-Fallow-Sorghum, HI	(Ac.)								160.5	75.7		151.0	
Wheat Dryland	(Ac.)	152.7	47.5	637.7	152.7	2.0	1223.8	720.0	299.6	801.3	720.0	338.5	1179.4
Grain Sorghum Dryland	(Ac.)	567.3	711.9	453.1	567.3	731.9	210.4		557.4	355.0		536.0	248.9
Stockers	(Hd.)	904	843	1,068	904	826	1,304	826	898	1,104	826	904	1,306
Well Capacity	(GPM)	750.0	382.8	196.4	750.0	397.2	253.6	750.0	361.0	181.6	750.0	361.5	239.5
Cost/Ac. In.	($)	0.99	1.75	3.24	0.99	4.43	10.75	0.99	1.85	3.49	0.99	4.85	11.37
NG Price/ mcf	($)	0.75	0.75	0.75	0.75	2.97	5.00	0.75	0.75	0.75	0.75	2.97	5.00
Water Applied	(Ac.In.)	15,460	10,166	5,216	15,460	10,549	138	16,399	10,221	5,302	16,399	10,170	0

[a]Natural gas is assumed to rise from $0.75 in period 1 to $1.75 in period 2 and then increase gradually to $5.00 per thousand cubic feet in period 10.

[b]HI, MI and LI represent high level, moderate level and low level of irrigation, respectively.

Conventional vs. Reduced and Conventional Tillage

To offset the decline in net returns caused by rising natural gas prices, producers may wish to consider more profitable reduced tillage production practices. The effects on optimal production organization of introducing reduced tillage practices for the medium water situation and high crop prices are also summarized in Table 2. Introduction of reduced tillage activities greatly changes the production organization. For example, when only conventional tillage practices are considered, irrigated activities are limited to corn grain, wheat, sorghum and soybeans. When conventional and reduced tillage practices are considered in the model, wheat and grain sorghum double-crop, the two-year rotation of conventional and reduced tillage wheat, and reduced tillage corn grain are the predominant irrigated activities in the optimum organization. Wheat at the moderate irrigation level is the only conventional tillage irrigated activity in the period 1 solution.

Net returns are about 10 percent higher in period 1 when reduced and conventional tillage practices are included in the model. However, reduced and conventional tillage practices utilize more water and result in lower well yields and higher pumping costs through time. By period 10, net returns for conventional and reduced and conventional tillage practices are approximately equal.

Cropping pattern shifts through time, when only conventional tillage is considered, involve a reduction in the number of irrigated acres of corn grain and sorghum and shifts to lower intensity irrigation levels for wheat and soybeans. When both conventional and reduced tillage practices are included, the changes in solutions through time are less orderly. However, under constant natural gas prices, about 284 acres remain in irrigated production in period 10 under conventional and reduced tillage versus nearly 350 acres when only conventional tillage practices are considered in the model. Under rising natural gas prices, a complete shift to dryland production occurs over the 50-year period regardless of the tillage practices considered. The switch to dryland production is somewhat more rapid under reduced and conventional tillage.

A shift to reduced tillage production practices to offset the effects of rising natural gas prices increases net returns in the short run. However, over time the increased water use combines with rising natural gas prices to reduce net returns to the level achieved under conventional tillage practices.

Low vs. High Product Prices

A series of programming runs were made to determine the potential effects on cropping pattern, net returns, water use and pumping costs of variations in product prices. Table 3 presents optimal production organization for periods 1, 5 and 10 under low and high product prices for representative farms utilizing conventional tillage practices in poor and good water resource situations. The implications of product price variations are quite similiar for farms across all three water resource situations. As expected, high product prices encourage more intensive irrigation practices, other things equal.

In the poor water situation, high crop prices result in increased water use. Consequently, well capacity declines more rapidly and pumping costs per acre inch increase more rapidly under high product prices. However, high product prices more than offset higher pumping costs, resulting in greater net returns. For low product prices, net returns decline from $67,775 to $42,967 (about 37 percent) over the 50 year period. About 130 acres remain under irrigation, 90 acres of which are in wheat at the low irrigation level. Under high crop prices, the decline in net

Table 3. Comparison of Optimal Organization for Low vs. High Crop Prices, Conventional Tillage, Poor and Good Water Situations

		Poor Water Situation						Good Water Situation					
		Low Prices			High Prices			Low Prices			High Prices		
Column		(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
Period		1	5	10	1	5	10	1	5	10	1	5	10
Net Returns	($)	67,775	50,112	42,967	141,919	88,856	70,948	64,716	60,481	48,477	158,856	133,305	90,990
Corn Grain	(Ac.)	88.8	58.3		133.3	50.6	23.7	2.3	2.3	67.2	118.4	215.0	86.7
Wheat, HI[a]	(Ac.)										192.5		
Wheat, MI	(Ac.)				399.8	151.6	71.2					391.9	260.2
Wheat, LI	(Ac.)	399.8	174.8	90.1				457.5	457.5	389.3			
Sudan Hay, HI	(Ac.)	38.4	38.7	30.0				39.1	39.1	38.6			
Grain Sorghum, LI	(Ac.)		19.4		44.4	16.8	7.9			81.3		40.0	28.9
Soybeans, HI	(Ac.)	94.9	0.2					221.0	221.0	9.9	409.1	73.0	
Soybeans, LI	(Ac.)				133.3	50.5	23.7						86.7
Wheat Dryland	(Ac.)	534.7	915.9	1110.1		779.7	1034.1	486.7	486.7	557.9	549.0		473.3
Grain Sorghum Dryland	(Ac.)	283.4	232.8	209.7	729.3	390.9	279.3	233.3	233.3	295.8	170.9	720.0	504.2
Stockers	(Hd.)	1,280	1,289	1,306	823	1,122	1,220	1,305	1,305	1,286	1,057	807	991
Well Capacity	(G.P.M.)	400.0	174.7	90.1	400.0	151.6	71.2	950.0			950.0	518.5	260.2
Cost/Ac. In.	($)	0.77	1.58	2.93	0.77	1.80	3.65	1.05	1.46	2.32	1.05	1.79	3.37
Water Applied	(Ac. In.)	8,528	3,942	1,051	10,616	4.024	1,890	9,959	9,959	6,786	16,125	12,057	6,909

[a]HI, MI and LI refer to high level, moderate level and low level of irrigation, respectively.

return is from $141,919 to $70,948, slightly more than 50 percent. Nearly the same number of acres remains under irrigation, but in more intensive activities such as corn grain and wheat at the moderate irrigation level.

The level of product prices appears to be a very important factor in determining the length of time over which producers will find irrigation profitable. For the poor water situation, a decline in product prices from high to target price levels would reduce the length of time horizon over which an irrigator could recover both fixed and variable irrigation costs by 50 percent. In the moderate and good water situations, the length of time horizon over which irrigation is profitable is reduced by 30 percent and 10 percent, respectively.

CONCLUSIONS

Rising natural gas prices have several potential effects. First, they increase the cost of pumping irrigation water and, other things equal, reduce the level net returns associated with irrigated crop production. Second, the pattern of irrigated crop production and the level of water use through time are similiar for both constant and rising natural gas prices. Shifts from high to moderate levels of irrigation occur both under constant and increasing natural gas prices due to changes in the water table and pumping costs. Third, the shift from irrigated to dryland crop production occurs more rapidly under rising natural gas prices than under constant prices. About a two-thirds reduction in net returns accompanies rising natural gas prices and the return to dryland production. This result holds across water resource situations and for alternative tillage practices.

Adoption of reduced tillage production practices increases the level of water use under irrigated crop production. The optimum organization of production shifts from conventional tillage corn grain, wheat, sorghum and soybeans to wheat and grain sorghum double-crop, a two year rotation of conventional and reduced tillage wheat, and reduced tillage corn grain. Net returns are higher during initial periods under reduced tillage technology. However, over time, higher water-use rates and the declining water table combine to increase pumping costs significantly and equalize net returns.

This analysis suggests that producers in the Oklahoma Panhandle have good reason for concern regarding the level of crop prices. Net returns under low crop prices are only 40 to 50 percent of net returns under high crop prices. In the poor water situation, the time horizon over which producers will find it profitable to irrigate under high crop prices is approximately twice as long as the time horizon under low crop prices. We have heard much discussion the past two years regarding the effects of changes in input prices. This analysis suggests farm operators, as well as those financing operating inputs, machinery purchases and land, have a vested interest in the level of product prices.

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FOOTNOTES

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[1] Input-output data for the conventional tillage cropping activities are based on practices of the more efficient producers in the area. Thus, conventional tillage represents somewhat fewer tillage operations than the average for the area.

[2] The low set of output prices, based on 1976 target prices are: wheat, $2.29 per bushel; corn, $1.57 per bushel; grain sorghum, $2.66 per hundredweight; soybeans, $3.28 per bushel; sudan hay, $22.00 per ton and corn silage, $6.34 per ton.

[3] The high set of crop prices is based on an assumed wheat price of $3.50 per bushel. Other prices are calculated based on their average levels relative to average wheat prices during the 1969-73 period.

Other prices are: corn, $2.89 per bushel; grain sorghum, $4.68 per hundredweight; soybeans, $6.46 per bushel; sudan hay, $33.60 per ton; and, corn silage, $11.20 per ton.

[4]It is assumed that the natural gas price increases from $0.75 per thousand cubic feet (mcf) in period 1, to $1.75 per mcf in period 2 and then gradually rises to $5.00 per mcf by period 10. These assumptions are arbitrary, however, $0.75 per mcf represents an average price for early 1976 and natural gas contracts are currently being re-negotiated for $1.75-$1.85 per mcf in portions of the study area.