

# **ECONOMICS OF SURFACE AND SPRINKLER IRRIGATION SYSTEM CONVERSION FOR LOWER CAPACITY SYSTEMS**

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## **INTRODUCTION**

The profitability of converting from furrow surface irrigation to a center pivot sprinkler irrigation system depends upon a number of factors. These include a) the pumping capacity of the irrigation well, b) the cost of converting to the sprinkler irrigation system and loan repayment period, c) changes (if any) in irrigated acreage, and d) comparative irrigated crop yields for the old and new systems. Labor savings are also commonly thought to be a major consideration in switching from furrow surface irrigation to center pivot irrigation systems. Other factors considered include long run crop prices, production costs, and tax-related depreciation and interest deductions for the pivot system investment.

A number of studies have been performed to analyze the profitability of irrigation system conversion (Dhuyvetter 1996; Williams, et.al. 1996). These studies have typically relied on a number of assumptions about initial furrow irrigated field size and crop yields, irrigation well capacity and irrigation system water application efficiencies, crop yields and net returns, labor use for alternative irrigation systems, and sprinkler irrigation system investment and pump repair costs. Lamm, et.al. 1997, have focused on the impact of sprinkler irrigation capacity on corn yield potential and economics. Lower irrigation pumping capacities were shown to affect both crop yields and net returns under western Kansas conditions, particularly in high water use years when limited irrigated water applications were unable to fulfill crop needs.

This study focused on the impact of differing irrigation well pumping capacities and weather conditions upon irrigated corn yields and the profitability of converting from furrow surface irrigation to center pivot irrigation systems. The analysis concentrated on irrigation system capacities of 700 gallons/minute (gpm) and less. The value of labor savings gained by switching from furrow surface irrigation to center pivot irrigation systems was also examined. The

results of this analysis are presented on an annual basis over the life of the alternative irrigation systems, accounting for the impact of tax deductions and debt repayment on annual cash flows.

## PROCEDURES USED

This analysis assumed that a crop producer with a furrow surface-irrigated quarter section of farmland was determining whether or not to convert to a center pivot irrigation system. The existing furrow surface irrigation system produced 160 acres of irrigated corn and was assumed to have an improved furrow irrigation application efficiency of 70%. The center pivot sprinkler irrigation system would produce 125 acres of irrigated corn. The remaining 35 acres in the corners of the 160 acre field would no longer be irrigated, but instead are placed in a wheat-corn-fallow rotation. Alternative center pivot sprinkler irrigation system application efficiencies of 85% and 100% were examined in this study.

### **Center Pivot Sprinkler Investment Costs & Tax Deductions**

Current budget estimates from KSU Farm Management Guide MF-836 (Irrigation Capital Requirements and Energy Costs) as well as irrigation industry cost projections were used to estimate the purchase cost of a sprinkler irrigation system (Table 1). An additional \$4,500 was budgeted to modify the existing well pump for the higher pressure requirements of sprinkler irrigation. The cost of the pivot sprinkler system was \$45,209, including a standard 7 tower pivot system with drops, low drift nozzles, underground pipe from the field edge to the pivot point, electrical wiring and connectors, and an electric generator. The total system and pump modification costs were \$49,709.

Table 1. Capital Requirements for a Center Pivot irrigation System (125 acres).

Item	Feet	Price/ft	Costs
Standard 7 Tower Center Pivot System Base Price	1,320		\$28,000
Drops on 80" Spacing			2,100
Low Drift Nozzles			2,400
38" x 11.2 Tires			3,000
8" Underground Pipe	1,320	\$2.52	3,326
Electrical Wiring	1,320	\$1.90	2,508
Connectors			1,500
12 KVA Generator			<u>2,375</u>
Total Cost of Center Pivot System			\$45,209
Pump Modification Cost			<u>\$4,500</u>
Total System & Pump Cost			\$49,709

The MACRS 150% Declining Balance method (7 years) was used to calculate tax depreciation. Both principal and interest payments were calculated for a 5 year amortized note at 10% interest, with the total payment for each of the 5 years equaling \$13,113 per year. The combined federal (15%), state (6%), and self employment (15.3%) tax rate used here was 36.30%. In the final after tax profitability calculations this same combined total tax rate was used.

### **Water Application Rates and Well Pumping Capacities**

A key aspect of this analysis involved the comparison of irrigated corn yields and net returns across a range of five different gross irrigation pumping capacities for alternative irrigation systems (Table 2.). Irrigation schedules (water budgets) were simulated for the 1972-1998 period using climatic data from the KSU Northwest Research-Extension Center in Colby, Kansas. Irrigation was scheduled as needed according to the climatic conditions, but was limited to the frequencies for the two systems as indicated in Table 2. The irrigation season was limited to the 90 day period between June 5 and September 2. The first furrow surface irrigation event in each year was on June 15, reflecting a typical date of first irrigation following the final furrowing process. After that, furrow irrigation events were scheduled as the capacity limitation allowed and if the calculated irrigation deficit exceeded 3 inches. Center pivot sprinkler irrigation events were scheduled during the 90-day period as the capacity limitation allowed and if the calculated irrigation deficit exceeded 1 inch.

Table 2. Equivalent Irrigation Frequencies and Pumping Capacity for Furrow Surface and Center Pivot Sprinkler Irrigation Systems.

<u>Gross Irrigation Capacity</u> Inches per Day	Center Pivot		Furrow Surface	
	Frequency & Amount Applied	Flowrate Gpm per 125 acres	Frequency & Amount Applied	Flowrate Gpm per 160 acres
0.250"	1" in 4 days	589	3" in 12 days	754
0.200"	1" in 5 days	471	3" in 15 days	603
0.167"	1" in 6 days	393	3" in 18 days	503
0.125"	1" in 8 days	295	3" in 24 days	377
0.100"	1" in 10 days	236	3" in 30 days	302

### **Corn Yields**

Irrigated corn yields for the various alternative irrigation systems and irrigation capacities were also simulated for the same 27 year period using the evapotranspiration (ET) estimates from the irrigation schedules and using a yield production function developed by Stone et al. (1995). In its simplest form, the model results in the following equation,

$$\text{Yield} = -184 + (16.85 \text{ ET})$$

with yield expressed in bushels/ acre and ET in inches. Further application of the model reflects weighting factors for specific growth periods. These

additional weighting factors were incorporated into the simulation to better estimate the effects of irrigation timing for the various systems and capacities. These weighting factors and their application to the model are discussed in detail by Stone et al. (1995).

### **Crop Revenues, Costs, and Net Returns**

In these profitability projections, the long term corn selling price was assumed to be \$2.42/ bushel. USDA Production Flexibility Contract payments on irrigated corn acres were assumed to be \$35/ acre. The long term wheat selling price was assumed to be \$3.22/bushel with wheat yields assumed to average 45 bushels/acre. Dryland no-till corn yields were assumed to average 75 bushels/acre. Production Flexibility Contract payments on dryland wheat and corn acres were assumed to be \$10/acre. The fuel, oil, and maintenance cost of applying irrigation water through a center pivot was assumed to be \$2.25/acre-inch, and \$1.94/acre-inch for surface irrigation systems.

No land costs were assumed in these budgets to avoid the effects of varying land rental or purchase market conditions in the High Plains region. These analyses were performed both with and without KSU labor cost estimates included for the alternative crop enterprises. By paying special attention to labor costs it may be possible to determine the degree to which claims of labor savings from system conversion are valid or not. In the following analyses, profitability estimates that represent returns to land, labor, and management do not include labor cost estimates. When labor cost estimates were accounted for, profitability measures represent returns to only land and management.

The time period for this analysis was 15 years. This time span was a conservative approximation of the expected life span of a newly purchased center pivot system. No inflation or deflation in crop prices or input costs was assumed during the 15-year period.

Long term average crop selling prices and production costs were taken from KSU Farm Management Guide Budgets. Specific budgets used included those for Center Pivot Irrigated Corn In Western Kansas (MF-585), Flood Irrigated Corn in Western Kansas (MF-578), Wheat in a W-S-F Rotation in Western Kansas (MF-903), and No-Till Corn in a W-C-F Rotation in Western Kansas (MF-2150). Long term planning prices for western Kansas for corn and wheat were taken from Prices for Crop and Livestock Cost-Return Budgets (MF-1013). Specific information on the seed, fertilizer, herbicide, insecticide, fuel, oil, machinery, crop insurance, operating interest, and other costs used here are found in the KSU Farm Management Guide budgets, and are available from either the authors or through county extension offices in Kansas and other states.

## RESULTS

### Long Term Average Irrigation Requirements and Corn Yields

The simulated irrigation schedules and corn yield model were used to generate estimates of the irrigation requirement and corn yields for the various irrigation systems and capacities for each year (1972-1998). This data was summarized into averages, standard deviations, and maximum and minimum values of irrigation requirements and corn yields (Table 3). Standard deviation is used here as a measure of variability. The higher the standard deviation of a particular value the higher the variability of the estimate and vice versa.

The 1 inch/4 days (589 gpm on 125 acres) gross irrigation capacity generates average yield estimates of 196 and 192 bu./acre for the 100% efficient center pivot system (CP100%) and the 85% efficient center pivot (CP85%), respectively (Table 3). The equivalent 3 inches/12 days (754 gpm on 160 acres) estimated an average yield of only 174 bu./acre for the 70% efficient furrow surface irrigation system (FS70%). Gross irrigation requirements for the three systems, CP100%, CP85% and FS70% were 13.3, 14.6 and 16.4 inches, respectively.

As gross irrigation system capacity declined further, the yields for each of the three irrigation systems declined. However, CP100% yields declined less than CP85% yields (from 196 to 140 bu./acre versus from 192 to 130 bu./acre). Yields for FS70% trailed both CP100% and CP85%, declining from 174 to 118 bu./acre. Yield results for FS70% were most variable across the alternative irrigation capacities. Water application amounts per acre were higher for FS70% than for CP85%, which in turn were higher than for CP100% (Table 3).

Corn yields were also simulated for full irrigation (Table 3). Under full irrigation, adequate irrigation water is supplied to meet the crop's evapotranspiration needs without potential timing delays caused by inadequate irrigation system pumping capacity. In essence, irrigation water is being supplied to the crop at the same rate in which the crop is using it. The results show that if full irrigation were possible for all three systems (100% efficient center pivot, 85% efficient center pivot, and 70% efficient furrow surface irrigation), equal corn yields of 197 bushels/acre would be obtained. However the average irrigation water application for the three systems would be 13.9, 16.5, and 20.2 inches for the CP100%, CP85%, and FS70% systems, respectively.

Table 3. Average Irrigated Corn Yields and Irrigation Application Amounts for 1972-1998<sup>a</sup>.

	0.25"/day		0.20"/day		0.167"/day		0.125"/day		0.10"/day		Full Irrigation	
	Irr. Amount (in)	Corn Yield (bu/a)	Irr. Amount (in)	Corn Yield (bu/a)	Irr. Amount (in)	Corn Yield (bu/a)	Irr. Amount (in)	Corn Yield (bu/a)	Irr. Amount (in)	Corn Yield (bu/a)	Irr. Amount (in)	Corn Yield (bu/a)
<b>A. Center Pivot Sprinkler System @ 100% Application Efficiency on 125 acres (CP100%)</b>												
Frequency	1" in 4 days		1" in 5 days		1" in 6 days		1" in 8 days		1" in 10 days		Full Irrigation	
GPM Rate	589 gpm		471 gpm		393 gpm		295 gpm		236 gpm			
Average	13.3	196	12.0	188	10.7	13.9	8.6	156	7.2	140	13.9	197
Std Deviation	3.9	43	3.1	36	2.4	4.2	1.7	24	1.2	25	4.2	44
Minimum	5	111	5	111	5	5	4	103	4	92	5	111
Maximum	20	261	17	254	14	21	11	188	9	174	21	269
<b>B. Center Pivot Sprinkler System @ 85% Application Efficiency on 125 acres (CP85%)</b>												
Frequency	1" in 4 days		1" in 5 days		1" in 6 days		1" in 8 days		1" in 10 days		Full Irrigation	
GPM Rate	589 gpm		471 gpm		393 gpm		295 gpm		236 gpm			
Average	14.6	192	12.9	179	11.4	166	9.0	145	7.4	130	16.5	197
Std Deviation	3.9	39	2.9	30	2.1	25	1.6	25	1.2	27	5.1	44
Minimum	6	111	6	111	6	108	5	94	4	74	6	111
Maximum	20	259	17	235	14	201	11	182	9	174	25	269
<b>C. Furrow Surface Irrigation System @ 70% Application Efficiency on 160 acres (FS70%)</b>												
Frequency	3" in 12 days		3" in 15 days		3" in 18 days		3" in 24days		3" in 30 days		Full Irrigation	
GPM Rate	754 gpm		603 gpm		503 gpm		377 gpm		302 gpm			
Average	16.4	174	14.4	160	13.0	149	10.6	132	8.4	118	20.2	197
Std Deviation	4.2	32	3.4	28	2.9	27	2.1	28	1.5	30	6.2	44
Minimum	6	103	6	88	5	75	4	60	3	50	6	111
Maximum	21	233	18	203	15	181	12	171	9	162	30	269

a. Based on 1972-1998 climatic conditions at the Northwest Research Extension Center in Colby, Kansas, and on the Stone et al. (1995) corn yield prediction model.

Regression equations for yields as related to irrigation capacity were generated. This allowed the calculation of corn yields for specific irrigation well capacities ranging from 200 to 700 gpm for three alternative systems (Figure 1). This perspective is important to decision makers in the Central Great Plains of Kansas who often are dealing with wells with pumping capacities in this capacity range. For similar well pumping capacities, CP100% average corn yields ranged from 3 to 11 bu./acre higher than for CP85% corn yields across of the range of well capacities considered here (i.e., 200 to 600 gpm for center pivots) on 125 acre fields. However, average corn yields for FS70% on 160 acre fields are from 28 to 33 bu./acre lower than CP85% yields for wells in the 300 to 600 gpm pumping capacity range. The impact of lower furrow surface-irrigated corn yields on this analysis of conversion profitability will depend in part on how profitable the nonirrigated crop production on the 35 acres in the center pivot corners is. No 200 gpm yield outcomes are presented for FS70%, and no 700 gpm yield outcomes are presented for CP100% and CP85% because this would require extrapolation beyond the range of the generated equations.

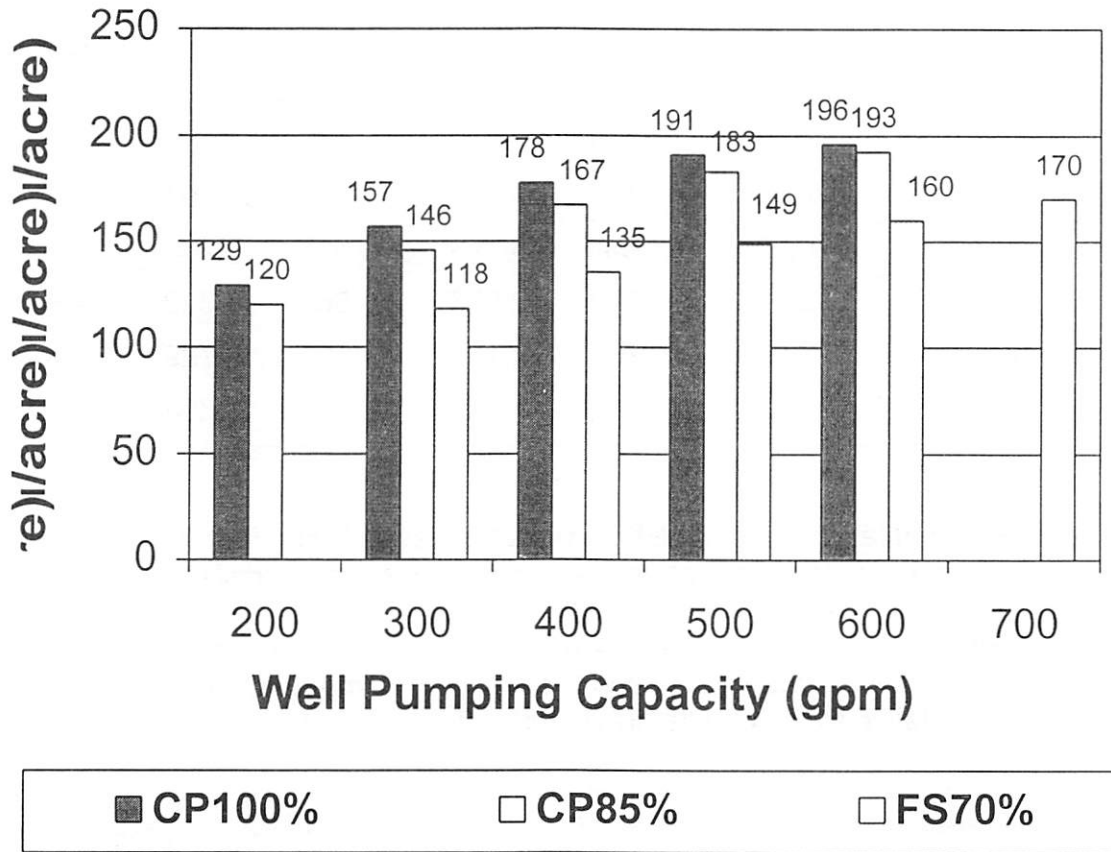


Figure 1. Irrigated Corn Yields as affected by Well Pumping Capacity, Irrigation System and Application Efficiency.

## **Annual After-Tax Net Returns**

Regression equations were also generated for annual after tax net returns to land, labor and management as related to irrigation capacity for the three irrigation systems. The results are shown in Table 4 and Figure 2. These findings indicate that it is profitable to convert from furrow surface irrigation to center pivot irrigation systems, given the yield results and cost-return assumptions used in this study. At 600 gpm well pumping capacities, both the center pivot irrigation systems examined have \$9-14 per acre annual net returns advantages over furrow surface irrigation systems. As well pumping capacity declines to 300 gpm, the disadvantage of furrow surface irrigation increases to \$29/acre and \$16 per acre relative to 100% and 85% efficient center pivots, respectively.

Table 4. After Tax Net Returns for Alternative Irrigation Systems.  
(Returns to Land, Labor, and Management)

Pump Capacity (gpm)	Center Pivot 100% Efficiency		Center Pivot 85% Efficiency		Furrow Surface 70% Efficiency	
	Total Net Revenue	Net Per Acre	Total Net Revenue	Net Per Acre	Total Net Revenue	Net Per Acre
200	\$1,951	\$12	\$262	\$2		
300	6,751	42	4,675	29	\$2,091	\$13
400	10,199	64	8,123	51	5,443	34
500	12,287	77	10,607	66	8,322	52
600	12,023	81	12,127	76	10,729	67
700					12,664	79

The inclusion of labor costs based on K-State Research and Extension budget estimates for these crop enterprises causes furrow surface irrigation net returns to be even lower relative to the center pivot sprinkler system returns. The addition of labor costs leads to a \$15/acre decline in center pivot after tax annual net returns, and a \$22/acre decline in furrow surface irrigation after tax annual net returns relative to the results presented in Table 4 and Figure 2.

These results are sensitive to assumptions about irrigated corn prices. A \$0.10/bushel increase (or decrease) in long term corn price leads to increases in after tax annual net returns/acre of \$8.40 for CP85%, \$8.76 for CP100%, and \$9.33 for FS70%.



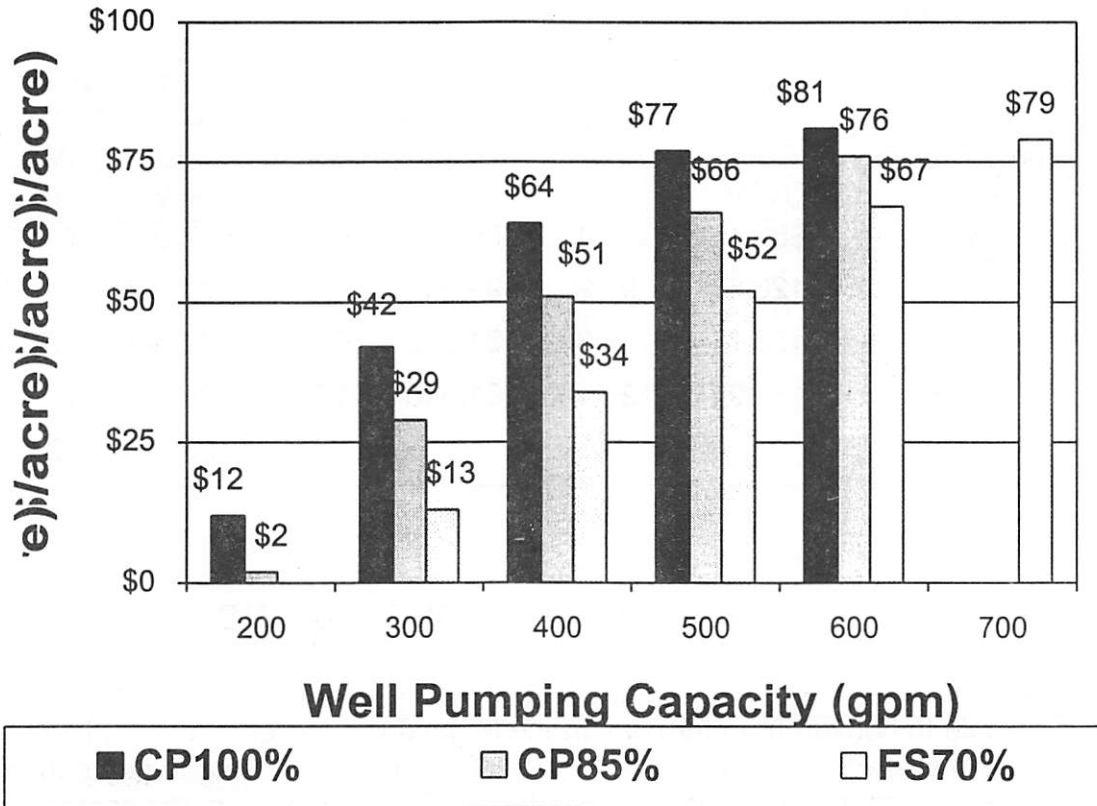


Figure 2. After Tax Net Returns for Alternative Irrigation Systems Per Acre (Returns to Land, Labor, and Management)

### After Tax Net Present Value Analysis

An analysis was made of the after tax net present value (NPV) of the existing furrow surface irrigation and the installed center pivot systems (Table 5). NPV is a financial analysis method used to account for the discounted value of future income. Essentially, income in a future time period is worth less than it is today because of the opportunity cost of interest. All present and discounted future income is summed to derive one NPV for a specific investment. The investment alternative with the highest net present value is the most profitable one to choose according to net present value analysis. Nominal and real inflation adjusted discount rates of 6.09% and 3%, respectively, were assumed in this analysis. These discount rates were further adjusted to reflect after tax NPVs.

Both the total after tax NPV findings and the annual average NPV estimates support the earlier conclusions of this paper that conversion from furrow surface irrigation to center pivot sprinkler irrigation is profitable. In the 300 to 600 gpm range of well capacities, the total after tax NPV values for the center pivot sprinkler irrigation systems are markedly higher than for the furrow surface irrigation system. This same finding is reflected in the annual average NPV findings.

**Table 5. Net Present Value (NPV) Analysis of Irrigation System Conversion Alternatives (After Tax Returns to Land, Labor, and Management)**

Pump Capacity (gpm)	Center Pivot 100% Efficiency		Center Pivot 85% Efficiency		Furrow Surface 70% Efficiency	
	Total NPV	Ave. NPV	Total NPV	Ave. NPV	Total NPV	Ave. NPV
300	\$82,100	\$6,347	\$55,245	\$4,271	\$27,052	\$2,091
400	126,667	9,793	99,848	7,719	70,405	5,443
500	153,714	11,884	131,982	10,203	107,649	8,322
600	163,241	12,619	151,646	11,723	138,784	10,729
700					163,811	12,664

## **SUMMARY AND CONCLUSIONS**

Under the crop production conditions assumed in this study, it was economically profitable to convert from furrow surface irrigation to center pivot sprinkler irrigation systems. This held true in spite of the irrigator having to pay principal and interest costs for the debt associated with the purchase of the center pivot sprinkler irrigation system as well as for pump modification costs, and having to switch 35 acres of previously irrigated cropland out of irrigated corn production and placing it in an intensive dryland cropping system (Wheat-No Till Corn-Fallow),.

Decreased irrigation well pumping capacity negatively affected both the production and profitability of the irrigated corn enterprise. For a 160 acre field, average irrigated corn yield estimates under furrow surface irrigation were dramatically reduced (170 to 118 bushels/acre) as irrigation well capacity declined from 700 to 300 gpm. To deal with this problem, producers typically reduce irrigated acreage to the level that they can still provide adequate water for irrigated crop growth. A future direction of this analysis may be to provide better information on how many acres of irrigated crop production can be adequately irrigated under these reduced well capacity scenarios, given the climate of the region. The associated economic analysis would be driven primarily by changes in irrigated corn yield levels and declines in irrigated acreage as producers seek to find the most productive and profitable irrigated acreage level given their limitation in water pumping capacity.

These findings support the claims of irrigators that labor savings are a factor that encourages them to convert from furrow surface irrigation to center pivot irrigation systems. When labor costs were accounted for in the analysis, the relative profitability of furrow surface irrigation system was made even worse in

comparison to the profitability of investing in a center pivot irrigation system. While labor is an important economic consideration, this analysis suggests that actual corn production levels with furrow surface irrigation versus a center pivot system were more important than labor considerations in the system conversion decision.

Earlier studies often found that the high initial investment costs for the center pivot irrigation systems typically made them less profitable relative to the existing furrow surface irrigation system. However, most of these studies were based on the expectation that furrow surface-irrigated corn yields would be approximately equal to those under center pivot irrigation. This analysis shows that as pumping capacity declines below moderate levels, furrow irrigation of larger fields becomes less profitable relative to investing in a center pivot system.

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