Economics of Surface to 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, 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 focuses 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 concentrates 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 are 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 assumes that a crop producer with a furrow surface-irrigated quarter section of farmland is determining whether or not to convert to a center pivot irrigation system. The existing furrow surface irrigation system produces 160 acres of irrigated corn and is assumed to have an improved furrow irrigation application efficiency of 70%. The center pivot sprinkler irrigation system will produce 125 acres of irrigated corn. The remaining 35 acres in the corners of the 160 acre field will 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% are 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 are used to estimate the purchase cost of a sprinkler irrigation system (Table 1). An additional $4,500 is budgeted to modify the existing well pump for the higher pressure requirements of sprinkler irrigation. The total cost of the pivot sprinkler system is projected to be $45,209, including a standard 7 tower pivot system with drops, low drift nozzles, underground pipe from the field edge to the

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			2,375
Total Cost of Center Pivot System			$45,209
Pump Modification Cost			$4,500
Total System & Pump Cost			$49,709

pivot point, electrical wiring and connectors and an electric generator. The total system and pump modification costs are $49,709.

The MACRS 150% Declining Balance method (7 years) is used to calculate tax depreciation. Both principal and interest payments are calculated for a 5 year amortized note at 9% interest, with the total payment for each of the 5 years equaling $12,780 per year. The combined federal (15%), state (6%) and self employment (15.3%) tax rate used here is 36.30%. In the final after-tax profitability calculations this same combined total tax rate is used.

Water Application Rates and Well Pumping Capacities

A key aspect of this analysis involves 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) are simulated for the 1972-1998 period using climatic data from the KSU Northwest Research-Extension Center in Colby, Kansas. Irrigation is scheduled as needed according to the climatic conditions, but is limited to the frequencies for the two systems as indicated in Table 2. The irrigation season is limited to the 90 day period between June 5 and September 2. The first furrow surface irrigation event in each year is on June 15, reflecting a typical date of first irrigation following the final furrowing process. After that, furrow irrigation events are scheduled as the capacity limitation allows and if the calculated irrigation deficit exceeds 3 inches. Center pivot sprinkler irrigation events are scheduled during the 90-day period as the capacity limitation allows and if the calculated irrigation deficit exceeds 1 inch.

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

	Center Pivot		**Furrow Surface**	
Gross Irrigation Capacity Inches per Day	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 are also simulated for the same 27 year period using the evapo-transpiration (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 are incorporated into the simulation to better estimate the effects of irrigation timing for the various systems and capacities. The 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 is assumed to be $2.36 per bushel in western Kansas. USDA Production Flexibility Contract payments on irrigated corn acres are assumed to be $35/ acre. The long term wheat selling price is assumed to be $3.18 per bushel with wheat yields assumed to average 44 bushels per acre. Dryland no-till corn yields are assumed to average 82 bushels per acre. Farm program Production Flexibility Contract (PFC) payments on dryland wheat and corn acres are assumed to be $10 per acre. The fuel, oil and maintenance cost of applying irrigation water through a center pivot is assumed to be $3.02 per acre-inch, and $2.62 per acre-inch for surface irrigation systems.

No land costs are assumed in these budgets to avoid the effects of varying land rental or purchase market conditions in the High Plains region. These analyses are 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 are accounted for, profitability measures represent returns to only land and management.

The time period for this analysis is 15 years. This time span is 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 is 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 an d corn yield model are use d to generate estimates of the irrigation requirement and corn yields for the various irrigation systems and capacities for each year (1972-1998). This data is 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 yield 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. per acre for the 100% efficient center pivot system (CP100%) and the 85% efficient center pivot (CP85%), respectively (Table 3). For the 70% efficient furrow surface irrigation system (FS70%) the equivalent application of 3 inches/12 days (754 gpm on 160 acres) leads to an average yield estimate of only 174 bu. per acre. Gross average irrigation requirements for the three systems, CP100%, CP85% and FS70% are 13.3, 14.6 and 16.4 inches per acre, respectively.

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

Corn yields are also simulated for full irrigation (Table 3). Under the full irrigation scenario, adequate irrigation water is supplied to meet the crop's evapo-transpiration needs without potential timing delays caused by inadequate irrigation system pumping capacity. In essence, irrigation water is being optimally supplied to the crop at the same rate in which the crop is using it. The analysis results show that if full irrigation is 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 per acre would be obtained. 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[a.]

	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)
A. Center Pivot Sprinkler System @ 100% Application Efficiency on 125 acres (CP100%)												
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	177	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. Center Pivot Sprinkler System @ 85% Application Efficiency on 125 acres (CP85%)												
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
C. Furrow Surface Irrigation System @ 70% Application Efficiency on 160 acres (FS70%)												

Frequency GPM Rate	3” in 12 days 754 gpm		3” in 15 days 603 gpm		3” in 18 days 503 gpm		3” in 24 days 377 gpm		3” in 30 days 302 gpm		Full Irrigation	
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 are generated for yields as related to irrigation capacity. This allows for the calculation of corn yields for specific irrigation well capacities ranging from 200 to 700 gpm for the three alternative irrigation systems (Figure 1). This perspective is important to decision makers in the Central Great Plains of Kansas who often are dealing with wells that have pumping capacities in this range. Projected annual average corn yields for CP100% ranged from 3 to 11 bu. per 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. per 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 depends 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.

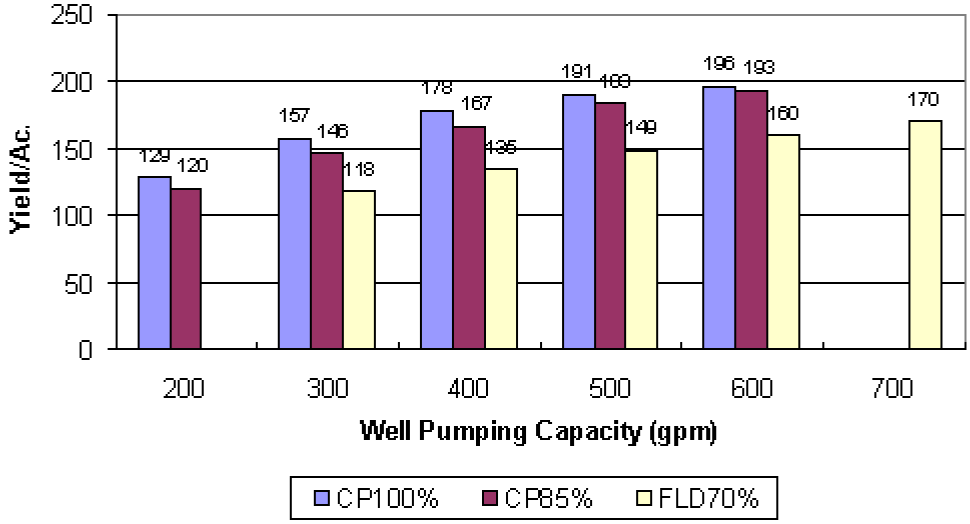

Figure 1. Irrigated Corn Yields as affected by Well Pumping Capacity, Irrigation System and Application Efficiency.

Annual After-Tax Net Returns

Regression equations are 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 $6 to $12 per acre annual net returns advantages over the furrow surface irrigation system. As well pumping capacity declines to 300 gpm, the advantage of center pivot systems over furrow surface irrigation increases to $25 per acre and $12 per acre for 100% and 85% efficient center pivots, respectively.

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

	Center Pivot 100% Efficiency		**Center Pivot 85% Efficiency**		**Furrow Surface 70% Efficiency**	
Pump Capacity (gpm)	Total Net Revenue	Net Per Acre	Total Net Revenue	Net Per Acre	Total Net Revenue	Net Per Acre
200	$2,063	$13	$408	$3		
300	6,566	41	4,516	28	$2,519	$16
400	9,783	61	7,716	48	5,602	35

500	11,714	73	10,009	63	8,253	52
600	12,360	77	11,396	71	10,473	65
700					12,262	77

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 in comparison to the results presented in Table 4 and Figure 2.

These results are sensitive to assumptions about 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 from $7.50 to $10.00 per acre for these center pivot and flood irrigated enterprises.

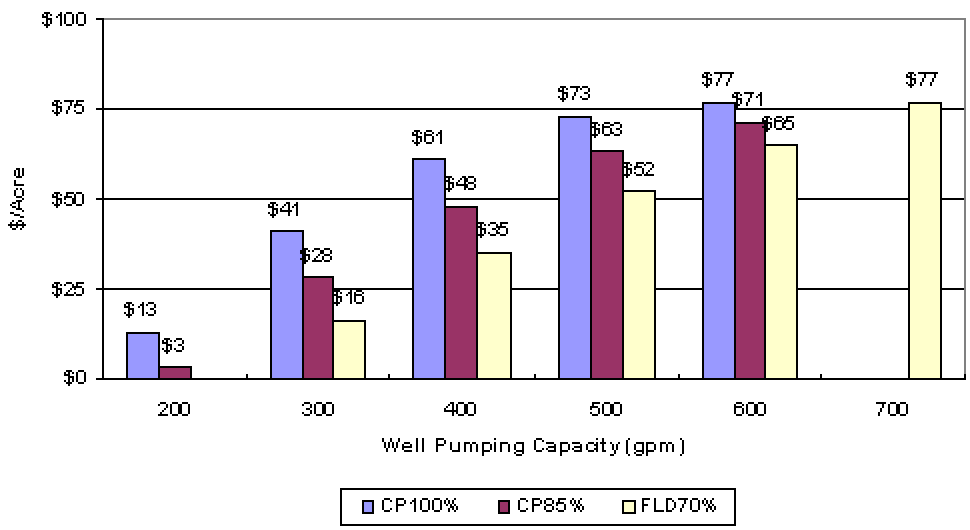

Figure 2. After-tax Net Returns for Alternative Irrigation Systems Per Acre (Returns to Land, Labor and Management)

SUMMARY AND CONCLUSIONS

This study shows that it is economically profitable to convert from furrow surface irrigation to center pivot sprinkler irrigation systems. These findings are dependent upon this study’s assumptions about production, costs, and returns fo the alternative irrigation systems. These results hold 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 and 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 (i.e., to a wheat-no till corn-fallow rotation).

Decreased irrigation well pumping capacity has a negative affect upon both the production and the profitability of an irrigated corn enterprise. For a 160 acre field, annual average irrigated corn yield estimates under furrow surface irrigation are dramatically reduced (170 to 118 bushels/acre) as irrigation well capacity declines 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 limited water pumping capacities.

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

Earlier studies typically 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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