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IRRIGATION MANAGEMENT SERIES

# The Economics of Converting from Surface to Sprinkler Irrigation for Various Pumping Capacities

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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 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 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 including *Dhuyvetter 1996 and Williams, et.al. 1996*. These studies have typically relied on a number of assumptions about the initial furrow irrigated field size and crop yield, irrigation well capacity, irrigation system water application efficiencies, crop yields and net returns, labor use for alternative irrigation systems, 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 on 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 per 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 square furrow, surface-irrigated quarter section of farmland is determining whether or not to convert to a center pivot irrigation system. The existing surface irrigation system produces 160 acres of irrigated corn and is assumed to have an irrigation application efficiency of 70 percent. 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 system application efficiencies of 85% and 95% 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 center pivot 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 center pivot 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 pivot point, electrical wiring and connectors and an electric generator. The total system and pump modification costs are $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 | | | 2,375 |
| Total Cost of Center Pivot System | | | $45,209 |
| Pump Modification Cost | | | $4,500 |
| Total System & Pump Cost | | | $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 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 Area Research and Extension Center, 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 the 90-day period between June 5 and September 2. The first surface irrigation event in each year is on June 15, reflecting a typical date of first irrigation following the final furrowing process. After that, surface irrigation events are scheduled as the capacity limitation allows and if the calculated irrigation deficit exceeds 3 inches. Center pivot 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.

| Gross Irrigation Capacity 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 are 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:

**Yield = -184 + (16.85 ET)**

with yield expressed in bushels per 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. United State Department of Agriculture (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/ bushel with wheat yields assumed to average 44 bushels/acre. Dryland no-till corn yields are assumed to average 82 bushels/acre. Farm Program Production Flexibility Contract (PFC) payments on dryland wheat and corn acres are assumed to be $10 /acre. The fuel, oil and maintenance cost of applying irrigation water through a center pivot is assumed to be $3.02 /acre-inch, and $2.62/acre-inch for surface irrigation systems.

No land costs are included 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 K-State 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

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 @ 95% Application Efficiency on 125 acres (CP95%)** | | | | | | | | | | | | |
| 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 | 13.8 | 195 | 12.3 | 188 | 10.9 | 177 | 8.7 | 159 | 7.2 | 146 | 14.6 | 197 |
| Std Deviation | 4.0 | 42 | 3.1 | 35 | 2.4 | 29 | 1.7 | 23 | 1.2 | 22 | 4.5 | 44 |
| Minimum | 5 | 111 | 5 | 111 | 5 | 111 | 4 | 104 | 4 | 96 | 5 | 111 |
| Maximum | 20 | 261 | 17 | 251 | 14 | 226 | 11 | 189 | 9 | 179 | 22 | 268 |
| **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 | 182 | 11.4 | 171 | 9.0 | 153 | 7.2 | 141 | 16.5 | 197 |
| Std Deviation | 3.9 | 39 | 2.9 | 31 | 2.1 | 26 | 1.6 | 23 | 1.2 | 23 | 5.1 | 44 |
| Minimum | 6 | 111 | 6 | 111 | 6 | 110 | 5 | 99 | 4 | 92 | 6 | 111 |
| Maximum | 20 | 259 | 17 | 239 | 14 | 210 | 11 | 188 | 9 | 178 | 25 | 268 |
| **C. Furrow Surface Irrigation System @ 70% Application Efficiency on 160 acres (FS70%)** | | | | | | | | | | | | |
| Frequency | 3" in 12 days | | 3" in 15 days | | 3" in 18 days | | 3" in 24 days | | 3" in 30 days | | Full Irrigation | |
| GPM Rate | 754 gpm | | 603 gpm | | 503 gpm | | 377 gpm | | 302 gpm | | | |
| Average | 16.9 | 180 | 14.9 | 168 | 13.3 | 158 | 10.9 | 144 | 8.7 | 132 | 20.4 | 197 |
| Std Deviation | 3.8 | 31 | 3.1 | 25 | 2.4 | 23 | 1.7 | 22 | 1.0 | 23 | 6.2 | 44 |
| Minimum | 6 | 111 | 6 | 109 | 6 | 104 | 6 | 94 | 6 | 89 | 6 | 111 |
| Maximum | 21 | 237 | 18 | 211 | 15 | 189 | 12 | 172 | 9 | 167 | 30 | 268 |

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.

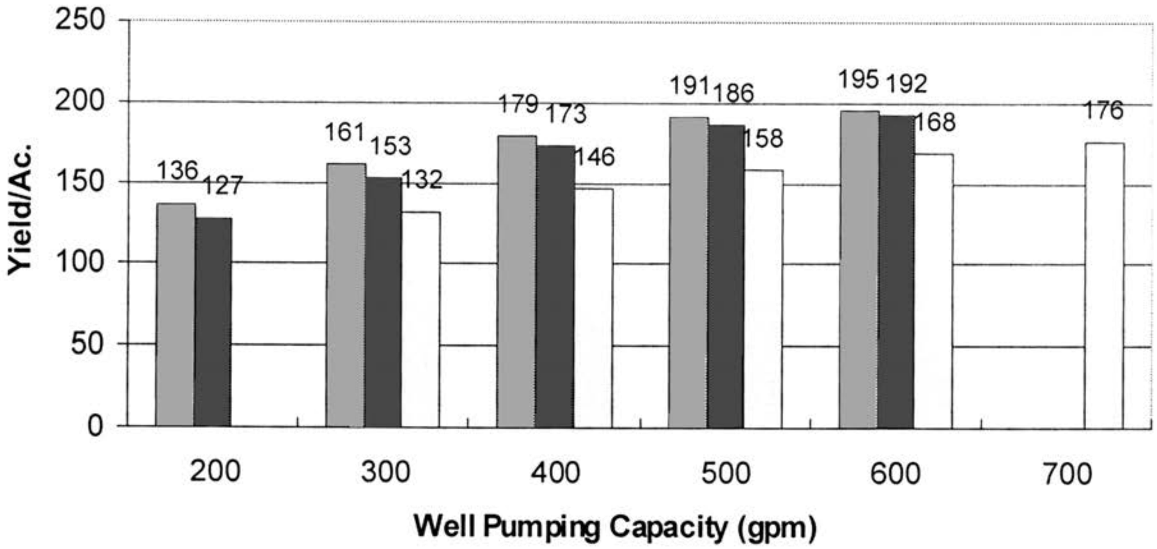


**Figure 1. Irrigated Corn Yields as affected by Well Pumping Capacity, Irrigation System and Application Efficiency.**

included those for: C*enter 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 local county Research and Extension offices in Kansas.

# RESULTS

## Long Term Average Irrigation Requirements and Corn Yields

The simulated irrigation schedules and corn yield model are 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 is summarized into averages, standard deviations, and maximum and minimum values of irrigation requirements and corn yields (Table 3). Standard deviation is used 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 195 and 192 bushels/acre for the 95 percent efficient center pivot system (CP95 percent) and the 85 percent efficient center pivot (CP85 percent), respectively (Table 3). For the 70 percent efficient furrow surface irrigation system (FS70 percent) the equivalent application of 3 inches/12 days (754 gpm on 160 acres) leads to an average yield estimate of only 180 bushels/ acre. Gross average irrigation requirements for the three systems, CP95 percent, CP85 percent and FS70 percent are 13.8, 14.6 and 16.9 inches per acre, respectively.

As gross irrigation system capacity declines further, the projected yields for each of the three irrigation systems decline. However, CP95 percent yields decline slightly less than CP85 percent yields (from 195 to 146 bushels/acre versus from 192 to 141 bushels/acre). Yields for FS70 percent trailed both CP95 percent and CP85 percent, declining from 180 to 132 bushels/per acre. Yield results for these three irrigation systems percent are nearly equal in variability across the alternative irrigation capacities. Water application amounts per acre are higher for FS70 percent than for CP85 percent, which in turn are higher than for CP95 percent (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 ET 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 (95 percent efficient center pivot, 85 percent efficient center pivot, and 70 percent efficient furrow surface irrigation), equal corn yields of 197

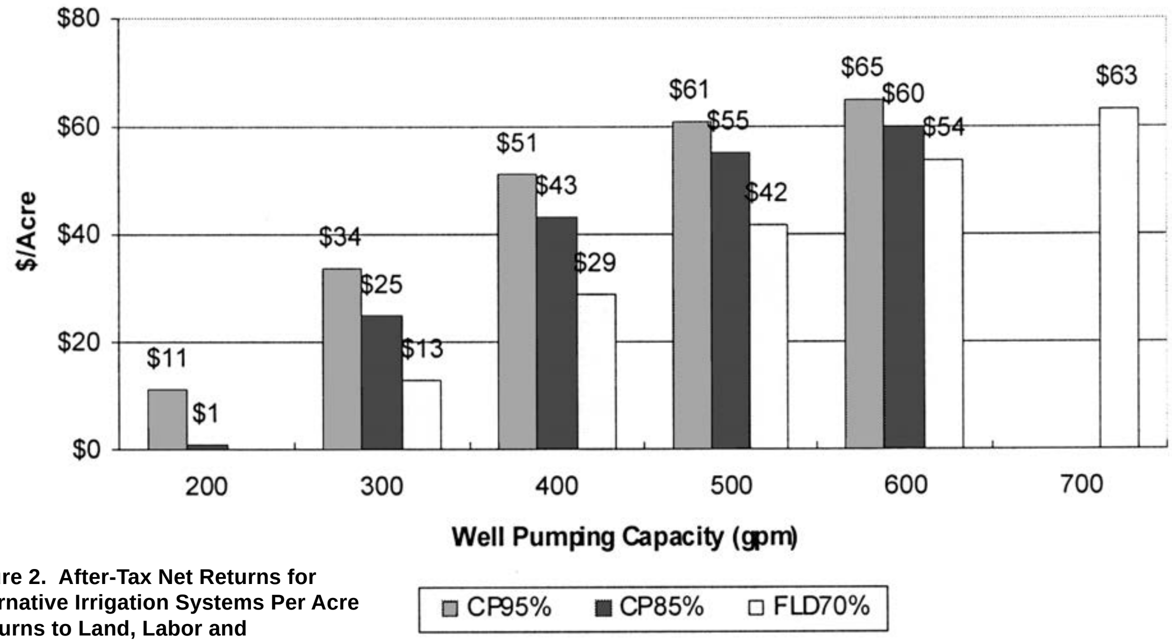


**Figure 2. After-Tax Net Returns for Alternative Irrigation Systems Per Acre (Returns to Land, Labor and Management)**

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

| Pump Capacity (gpm) | Center Pivot 95% 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 | $1,704 | $11 | $86 | $1 | | |
| 300 | 5,466 | 34 | 4,010 | 25 | $2,057 | $13 |
| 400 | 8,168 | 51 | 6,905 | 43 | 4,578 | 29 |
| 500 | 9,810 | 61 | 8,772 | 55 | 6,753 | 42 |
| 600 | 10,391 | 65 | 9,611 | 60 | 8,582 | 54 |
| 700 | | | | | 10,065 | 63 |

**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 95% Efficiency | | Center Pivot 85% Efficiency | | Furrow Surface 70% Efficiency | |
|---|---|---|---|---|---|---|
| | Total NPV | Ave. NPV | Total NPV | Ave. NPV | Total NPV | Ave. NPV |
| 300 | $65,490 | $5,063 | $51,911 | $4,013 | $26,602 | $2,057 |
| 400 | 100,442 | 7,765 | 90,009 | 6,958 | 59,214 | 4,578 |
| 500 | 121,675 | 9,407 | 113,339 | 8,761 | 87,349 | 6,753 |
| 600 | 129,188 | 9,987 | 121,188 | 9,423 | 111,009 | 8,582 |
| 700 | | | | | 130,194 | 10,065 |

bushels/acre would be obtained. The average irrigation water application for the three systems would be 14.6, 16.5, and 20.4 inches for the CP95 percent, CP85 percent, and FS70 percent systems, respectively.

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 are often dealing with wells that have pumping capacities in this range. Projected annual average corn yields for CP95 percent ranged from 4 to 9 bushels/acre higher, than for CP85 percent corn yields across 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 percent on 160 acre fields are from 21 to 28 bu./acre lower than CP85 percent yields for wells in the 300 to 600 gpm pumping capacity range. The impact of lower surface-irrigated corn yields on this analysis of conversion profitability depends in part on how profitable the non-irrigated crop on the 35 acres in the center pivot corners is. No 200 gpm yield outcomes are presented for FS70 percent, and no 700 gpm yield outcomes are presented for CP95 percent and CP85 percent,

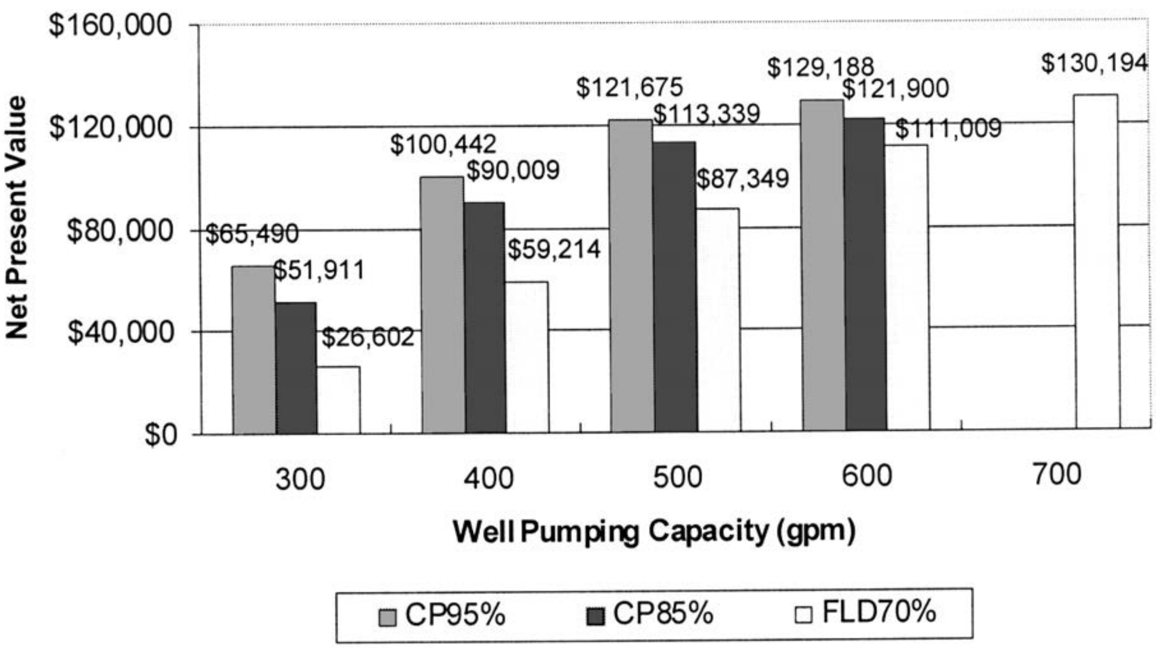


**Figure 3. After-tax Net Present Value of Alternative Irrigation Systems (Returns to Land, Labor and Management)**

because this would require extrapolation beyond the range of the generated equations.

## 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 $11 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 $21 per acre and $12 per acre for 95 percent and 85 percent efficient center pivots, respectively.

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/ acre for these center pivot and flood irrigated enterprises.

## After-Tax Net Present Value Analysis

An analysis is made of the after-tax Net Present Value (NPV) of the existing furrow surface irrigation and the installed center pivot systems (Table 5 and Figure 3). 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 NPV is the most profitable one to choose according to NPV analysis. Nominal and real inflation adjusted discount rates of 6.09 percent and 3 percent, respectively, were assumed in this analysis. These discount rates are 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, 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, even after the extra investment to establish the center pivot irrigation systems. This same result is shown in the annual average NPV findings.

## SUMMARY AND CONCLUSIONS

This study shows that it is economically profitable to convert from surface irrigation to center pivot irrigation systems. These findings are dependent upon this study's assumptions about production, costs, and returns of 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 irrigation system, 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 surface irrigation are dramatically reduced (180 to 132 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 a decline 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, encouraging them to convert from surface irrigation to center pivot irrigation systems. When labor costs were included in this analysis, the relative profitability of surface irrigation systems is made even worse compared 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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