An Economic Analysis of Flood and Center Pivot Irrigation System Modifications

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ABSTRACT

An after-tax net present value (NPV) analysis of investing in three irrigation system modifications for the production of corn, grain sorghum, wheat, and alfalfa is conducted. Modifying a high pressure center pivot with low-drift nozzles and adding surge valves to a gated pipe system is economically feasible for each crop.

Introduction

A major source of irrigation water in the western High Plains is the Ogallala aquifer. Available water from this source is declining because withdrawal rates are higher than recharge rates. Pumping costs are increasing because of greater pumping lift requirements and increasing energy costs. Lower well capacities, which usually result from declining water levels, also limit managers' irrigation scheduling options and increase the risk of crop water stress. As a result, irrigators in western Kansas are faced with the decision to invest in more efficient water distribution systems with greater application and fuel efficiencies or to remain with their existing system. Investment in new distribution-system technology has three potential net effects: the variable pumping costs per acre-foot can be reduced by lower fuel consumption per hour; the total variable cost per acre can be reduced by a higher application efficiency, which allows for less water to be pumped to obtain equivalent net application levels with fewer pumping hours; and yields and gross revenues can be increased by employing optimal irrigation scheduling which may have been previously constrained by low application efficiencies of an older system. Williams et al. (1996b) presents an analysis of investment in a new irrigation system when a current system is not in place. This report examines modifications of an existing system or changing to a new system from an existing system.

The economic analysis presented in this paper evaluates investment decisions for three irrigation system modifications: the modification of a high-pressure center-pivot system (HPCP) to a low-drift-nozzle center-pivot system (LDN); the addition of surge valves (SF) to a conventional furrow flood gated pipe system (FF); and the conversion from a conventional furrow flood gated pipe system (FF) to a low-drift-nozzle center-pivot system (LDN). These modifications are evaluated for production of corn, grain sorghum, wheat, and alfalfa.

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1 The mention of trade names or commercial products does not constitute their endorsement or recommendation by the author or by the Kansas Agricultural Experiment Station.

Procedures

An after-tax net present value analysis is used to assess the economic feasibility of the aforementioned modifications. The NPV analysis is conducted with the Irrigation Economics Evaluation System (IEES) microcomputer model (Williams et al. 1996a). The IEES program calculates operating and ownership costs for irrigation systems and can be used to analyze distribution system changes on an after-tax NPV basis. IEES estimates costs and returns over a ten year period and produces after-tax net present values for owning and operating a current and a proposed system. When the IEES program is used to evaluate switching or modifying distribution systems, field operation production costs, and yield and crop price estimates are included to estimate the net present value of the modification or system switch. The NPV of net returns represents the amount of money made or saved from switching or modifying the distribution system.

Irrigation Costs

Data required for IEES to calculate costs for each scenario are listed in Table 1. The flow rates and pumping water levels are 1994 averages from the Kansas State Board of Agriculture. The marginal tax rate is based on a four year average of net farm income from irrigated cash crop farms in the Kansas Farm Management Association. This average places these farms in the 15% federal tax bracket and the 6.25% state tax bracket. The resulting marginal tax rate is 35.38% (including a self employment tax rate of 14.13%). Irrigation fuel costs are based on a natural gas price of $2.50/mcf and are a function of the required horsepower and the number of hours that the pumping plant operates. Additional details concerning how operating costs are calculated can be found in Williams et al. (1996b).

Crop Production Costs

Production costs other than those estimated using IEES for operating the irrigation systems are from KSU Farm Management Guides (Langemeier). These costs include seed, herbicide, fertilizer, fuel and oil, crop machinery repair, and crop consulting. Total labor hours for the crop excluding irrigation labor are from Langemeier et al.

Crop machinery fixed costs, including depreciation, interest, and insurance are included as nonirrigation production costs. Depreciation and insurance costs are from the KSU Farm Management Guides. Machinery interest is equal to one-half of the original machinery cost multiplied by 8.2%. Machinery depreciation and interest costs for row crops are also adjusted to reflect the addition of the reservoir tillage tool when the LDN system is evaluated. Land costs, including real estate taxes and interest, are also included in the analysis and are from the KSU Farm Management Guides.

Yield and Price Estimation

Yields are estimated by entering an irrigation schedule, inches applied per application, and application efficiency in a yield simulator developed by Stone et al. The simulator assumes 16.4

inches of annual rainfall in addition to that applied by irrigation. Crop yield is determined in the model by evapotranspiration (ET) and available soil water.

Simulated yields are obtained by applying the available water in an economically optimal schedule, given depth per application feasible for each system and the time required for each irrigation event. Irrigation events are scheduled in an attempt to fully satisfy crop water requirements during the critical crop-development stages. Priority is given to meeting the crop water needs during head emergence for grain sorghum and wheat, and silking for corn. Numerous schedules are evaluated until the economic return from irrigation of the crop is maximized or the available irrigation water is exhausted by a maximum property right of 24 acre inches per year or the limiting well capacity and time interval during the season in which additional irrigation events potentially could enhance crop yields are exceeded.

Crop prices used are 5-year, average, national average price projections for 1995/1996 to 1999/2000 from the Food and Agriculture Research Institute. These prices are adjusted to western Kansas prices by comparing a ten year average price in western Kansas to a corresponding ten year average national price. The prices used to estimate gross revenue with the estimated yields are $2.62/bushel for corn, $2.35/bushel for grain sorghum, $3.36/bushel for wheat, and $71.96/ton for alfalfa.

System Modification Scenarios

Each system is assumed to be installed on a square quarter section with a well in the upper corner of the field. Flood systems are assumed to irrigate 158 acres while center pivot systems are assumed to irrigate 126 acres. When a flood system is replaced with a center pivot system, the production of wheat in a wheat-fallow rotation on the dryland corners is assumed. It is assumed that the existing power unit can be used to power the modified system and the terrain and soil type do not preclude the feasibility of any system. This analysis assumes the pumping plant is operating efficiently. Modifications to the pumping plant in the following scenario descriptions are only considered to be necessary to enable the proposed system to operate efficiently but are not necessary for an existing system.

High-Pressure Center Pivot (HPCP) to Low-Drift-Nozzle Center Pivot (LDN) Scenario

The existing high-pressure center pivot utilizes 60 impact sprinklers mounted on top of the lateral. The application efficiency is assumed to be 80%. Conversion to the low-drift-nozzle system requires installation of drop tubes and low drift nozzles. The nozzles are placed 30 inches above the ground 60 inches apart. The LDN system application efficiency improves to 90% because of decreases in evaporation and wind drift.

Two alternatives are available to the irrigator for conversion of the existing pump. The first alternative involves adjustment to the bowl(s) of the pump to allow for the drop in pressure from 75 psi to 18 psi which is required for this modification while maintaining power unit efficiency. This adjustment is a quick fix method which creates inefficiency in the pump. Efficiency of the pump, after adjustment, is estimated to be 51.7%. The second alternative is to pull the pump from the well and modify it to maintain or increase pump efficiency. The cost of modifying the pump requires an investment of $3,825. This investment will allow the pumping plant to operate at 80% efficiency (5% more on average than a currently existing pump). The LDN system also requires the purchase of a specialized implement for a reservoir tillage operation for the row crops in the analysis. This additional implement mounts behind a cultivator shank and is designed to implant small basins in the furrow to retain runoff. This operation is needed to maintain the irrigation application efficiency. A nine-row reservoir tillage tool is generally pulled behind an eight-row cultivator. This requires an investment of $2,296 per circle given the average number of circles per irrigated farm in western Kansas. The total investment for the addition of the low-drift-nozzle system package along with the reservoir tillage tool is $6,832. If the pumping plant is modified to maintain efficiency, it is $10,657.

Furrow Flood Gated Pipe (FF) to Surge Flood Gated Pipe (SF) Scenario

Furrow flood gated pipe systems operate typically with an application efficiency of 65%. The low application efficiency is due to nonuniform water distribution, resulting in deep percolation at the top of the field. Surge valves create an intermittent flow of water through the furrows and application efficiency is increased by reducing tailwater volume and reducing deep percolation. The installation of surge valves is expected to improve application efficiency to 75%. Two solar powered surge valves are assumed to be installed by the irrigator resulting in an investment of $3,246. Adjustments to the existing pump and power unit are unnecessary.

Furrow Flood (FF) to Low-Drift-Nozzle Center Pivot (LDN) Scenario

For this scenario, the existing underground line from the well to the furrow flood system is assumed to be in the wrong location for use with a new LDN center pivot. The existing gated pipe is assumed to have a salvage value of $4,488 (42.5% of the original investment). An investment in a reservoir tillage tool is included in the initial investment for the LDN system. Therefore, the initial investment costs for a new LDN center pivot include the pipe from well to center pivot, a center pivot, LDN nozzles, and a reservoir tillage tool minus the salvage value of the existing gated pipe. Adjustments to the pumping plant are also necessary due to higher operating pressure requirements. The net investment for the installation of the LDN system and pump modification is $46,103. Installation of the low-drift-nozzle system increases water application efficiency by 25% (from 65% to 90%). Under this scenario, 32 acres of a wheat-fallow rotation are produced on the dryland corners.

Results

Operating Costs

Operating cost savings from switching systems are observed for all scenarios and crops (Table 2). For the HPCP to LDN modified pump scenario, fuel cost savings accounted for a majority of the operating cost savings. Fuel cost savings had a much smaller impact in the FF system modifications. Under these scenarios (FF to SF and FF to LDN), fuel cost savings are observed only when fewer inches of water are applied by the new or modified system, and fuel costs actually increased for corn production under the LDN compared to the FF system even though fewer inches of water are applied. These results are due to the low operating pressure of the FF system in comparison to the LDN system and the relatively low application efficiencies of both flood systems. Relatively large labor cost savings are observed for the FF to SF and the FF to LDN. However, savings in labor costs under scenarios which included the LDN system are negated by high distribution system maintenance and repair costs. All other operating costs compared from system to system are within $1 per irrigated acre of each other.

<u>After-tax NPV Analysis</u>

Results of the after-tax NPV analysis for each crop and each system change are presented in Table 2. The after-tax NPV analysis is separated into three components including: operating costs savings, the difference in crop return, and the added ownership costs of the new system. After-tax NPV of net returns from switching systems is calculated by adding the present value of operating costs savings to the difference in the present value of crop return and then subtracting the added present value of ownership costs of the new system. The after-tax NPV of net returns from switching systems indicates whether changing distribution systems is economically feasible.

HPCP TO LDN

The analysis indicates that the addition of drop tubes and low drift nozzles to the high-pressure center-pivot system is economically feasible for the production of all four crops using both a modified and an unmodified pumping plant. However, when the existing pump receives only minor adjustments, net returns are considerably lower than those when the pump is modified. For example, net returns from switching to the LDN system for corn are $1,285 and $6,452 for the unmodified pump and the modified pump respectively. Similar results are obtained for grain sorghum, wheat, and alfalfa. The results of the analysis suggest that the benefits of increasing application efficiency are offset to some degree by increased operating costs, especially fuel costs, when an inefficient pumping plant is used. The analysis indicates it is economical to modify the pumping plant when switching to the LDN system. The production of alfalfa under the modified pump scenario has the highest after-tax NPV of net returns from switching systems. Corn is the second most profitable crop under the modified pump scenario. Both irrigated corn and alfalfa acres have been increasing in western Kansas while irrigated wheat and grain sorghum acres have been declining in the 1990s (Kansas Department of Agriculture). Crop returns increased for all crops under both pump scenarios because of the increased application efficiency of the LDN system.

FF to SF

The analysis also indicates that the addition of surge valves to the gated pipe furrow flood system is economically feasible for the production of all four crops. Under this scenario, positive after-tax net returns from modifying the system are largely due to increased net crop returns for corn and grain sorghum. Wheat and alfalfa yields are similar for both flood systems, but 4 inches less of gross water per acre per season is required by the SF system. The resulting operating costs savings under the SF system make the modification feasible for wheat and alfalfa. The relatively low initial investment cost of switching from FF to SF also contributes to the economic feasibility of the modification.

FF to LDN

The replacement of the furrow flood gated pipe system (FF) with a low-drift-nozzle (LDN) center-pivot system is not economically feasible for the production of any of the four crops. Under this scenario, high ownership costs of the new system produced negative after-tax net returns from switching systems. For wheat and alfalfa, reductions in crop returns also contributed to the infeasibility of the switch. Declines in crop returns are due to the reduction in irrigated acres (158 irrigated acres with FF to 126 irrigated acres with LDN).

Summary and Conclusions

The economic analysis presented in this paper evaluates investment decisions for three irrigation system modifications: the modification of a high-pressure center-pivot system (HPCP) to a low-drift-nozzle center-pivot system (LDN); the addition of surge valves (SF) to a conventional furrow flood gated pipe system (FF); and the conversion from a conventional furrow flood gated pipe system (FF) to a low-drift-nozzle center-pivot system (LDN). These modifications are evaluated for production of corn, grain sorghum, wheat, and alfalfa.

Two scenarios are examined for the modification of a high pressure center pivot to a low drift nozzle center pivot. One scenario involves making the modification without pulling and modifying the pump. In this case, savings in initial investment costs (and the resulting ownership costs) and increases in crop returns are partially offset by the higher operating costs of the inefficient pump. A second scenario under the HPCP to LDN modification involves pulling the pump and modifying it so that it would operate efficiently given the reduced pressure requirement of the LDN system. This scenario, is economically feasible for all four crops.

Two system modifications are examined for a furrow flood gated pipe system. The first modification involves the addition of surge valves to the system. The relatively low initial investment cost of the surge valves along with operating costs savings made this modification economically feasible for the production of all four crops. The second modification considered is replacement of the system with a LDN center pivot. This modification required an initial investment of $46,103 for corn and grain sorghum and $43,076 for wheat and alfalfa, which produced prohibitive ownership costs that were not recovered by operating cost savings. Additionally, loss of irrigated production on the pivot corners significantly lowered crop returns. As a result, it is not economically feasible to produce any of the crops under this scenario.

Table 1. Selected Inputs for Irrigation System Ownership and Operating Cost Estimates Using IEES

A.) Number of acres:

Sprinkler Systems	126 acres	
Flood Systems	158 acres	
Wheat-Fallow in Rotation	32 acres	→ (Center Pivot Scenarios)

B.) Operating pressure (PSI):

HPCP	75 PSI
LDN	18 PSI
FF	5 PSI
SF	5 PSI

Operating pressures are measured at the pump and are used to calculate water horsepower which in turn is used to calculate fuel consumption.

C.) Pumping water level: All systems depth to water 175 feet

D.) Flow rate (GPM):

Sprinkler systems	520 GPM
Flood systems	570 GPM

E.) Pump efficiency (%):

Initial System	75%
Inefficient LDN system	51.7%
Efficient pump after modification	80%

F.) Before tax interest rate (weighted average cost of capital): 8.20%

G.) Marginal tax rate: 35.38%

H.) Replacement cost of the distribution system (existing system):

HPCP	$41,216
FF	$19,222

Replacement costs are from Williams et al., 1996b. Distribution system replacement costs are used in IEES to calculate distribution system maintenance costs.

I.) Replacement cost of the distribution system (new system):

	Corn and Grain Sorghum	Wheat and Alfalfa
HPCP to LDN	$6,832	$4,536
FF to SF	$3,246	$3,246
FF to LDN	$45,372	$43,076

Replacement cost of the new distribution system is entered as the cost of modification plus any additional investment in machinery. It is used to calculate ownership costs of the new system.

Table 1. Selected Inputs for Irrigation System Ownership and Operating Cost Estimates Using IEES

J.) Application Efficiency

System			
HPCP	LDN	FF	SF
80%	90%	65%	75%

K.) Inches of water applied:

	System			
Crop	HPCP	LDN	FF	SF
CORN	21	23	24	24
SORGHUM	19.5	18	20	20
WHEAT	18	18	24	20
ALFALFA	18	18	24	20

Inches of water applied are from irrigation schedules which maximize net returns. Procedures presented by Williams et al. 1996b and Llewelyn et al. are used to determine these optimal schedules.

L.) Crop yields (bushels/acre or tons/acre for alfalfa):

	System			
Crop	HPCP	LDN	FF	SF
CORN	196.7	201	185.2	191.6
SORGHUM	121.5	122.7	113.8	117.3
WHEAT	72.5	73.8	72.4	72.3
ALFALFA	6.56	6.68	6.65	6.61

Crop yields are used in the calculation of net crop returns. Wheat fallow yields of 35.0 bu./acre are used for 32 acres of dryland wheat production on the non-irrigated field corners in the switch from flood to LDN center pivot.

Table 2. IEES After-tax Net Present Value Analysis				
	Scenario			
	HPCP to LDN		FF TO SF	FF to LDN
After-tax NPV	Unmodified Pump	Modified Pump		
Corn				
Operating Costs Savings	$134.21	$8,038.91	$1,009.90	$1,169.92
Crop Return Difference	$6,040.97	$6,040.97	$13,157.10	$3,559.64
Ownership Costs of New System	($4,890.17)	($7,628.00)	($2,323.40)	($28,219.99)
Net Returns From Switching Systems	$1,285.01	$6,451.87	$11,843.69	($23,490.43)
Grain Sorghum				
Operating Costs Savings	$4,927.36	$11,113.65	$769.93	$1,253.50
Crop Return Difference	$914.93	$914.93	$6,434.94	$2,268.73
Ownership Costs of New System	($4,890.17)	($7,628.00)	($2,323.40)	($28,219.99)
Net Returns From Switching Systems	$952.12	$4,400.57	$4,881.46	($24,697.75)
Wheat				
Operating Costs Savings	$2,518.87	$8,705.15	$6,055.81	$6,539.38
Crop Return Difference	$3,042.28	$3,042.28	($28.10)	($6,448.15)
Ownership Costs of New System	($3,246.75)	($5,984.58)	($2,323.40)	($26,576.57)
Net Return From Switching Systems	$2,314.39	$5,762.84	$3,704.31	($26,485.34)
Alfalfa				
Operating Costs Savings	$2,518.87	$8,705.15	$6,055.81	$6,539.38
Crop Return Difference	$3,837.20	$3,837.20	($1,216.29)	($26,155.19)
Ownership Costs of New System	($3,246.75)	($5,984.58)	($2,323.40)	($26,576.57)
Net Return From Switching Systems	$3,109.32	$6,557.77	$2,516.11	($46,192.38)

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PERFORMANCE OF IN-CANOPY SPRINKLERS

by

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The goal of a center pivot sprinkler system is to uniformly distribute water on the soil surface. Uniform application and infiltration of irrigation water in the soil gives plants equal access to water. To reduce energy costs, center pivots have been converted from high pressure to medium and low pressure systems, while maintaining application uniformity. Design engineers and manufacturers have developed new sprinkler devices that operate at low pressures. These changes provide agricultural water users the opportunity to reduce pumping costs and insure an even distribution of water to all of their crop.

The new low pressure sprinkler devices have been designed to include tubing, called drops, that place the devices closer to the crop. Bringing the sprinkler device closer to the crop reduces water lost through evaporation and drift. In an attempt to reduce water loss even further, some producers are placing nozzles within the corn canopy. In-canopy sprinklers are viewed as very efficient because no water is seen above the canopy. Based on the assumption of improved water delivery, the trend has been too lower pressure and operate within the crop canopy to improve irrigation efficiency and reduce pumping costs. However, there are several factors that must be considered before adopting this change. Several basic questions remain:

1) How much water is lost to evaporation and drift when low pressure sprinkler devices are operated above the crop canopy as compared to within the canopy?
2) What happens to application uniformity when sprinklers are operated within the crop canopy?
3) What impact does the uniformity of in-canopy sprinklers have on the efficiency of water application?

Sprinkler water losses

Water loss from sprinkler devices can be categorized into to three main areas, air loss, canopy loss and ground loss. Water loss in the air occurs through evaporation or drift from the field. Loss of water in the canopy occurs through evaporation of water from the plant leaves. Some water is also intercepted and stored in the whorls of the plant and is evaporated at a later time. Ground losses occur through runoff and evaporation of water from the soil surface. Water stored on the soil surface and later infiltrated is not considered a loss if it remains near the point of application.