Economic Feasibility of Converting Center Pivot Irrigation to Subsurface Drip Irrigation

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ABSTRACT

Advancements in irrigation technology have increased water use efficiency. However, producers can be reluctant to convert to a more efficient irrigation system when the initial investment costs are high. This study examines the economic feasibility of replacing low energy precision application (LEPA) center pivot sprinkler irrigation with subsurface drip irrigation (SDI). Specifically, the changes in net investment, variable costs, and total costs related to the conversion of irrigation systems are estimated. Then, these costs are used to evaluate the necessary increase in crop yields with a SDI system under alternative crop scenarios for conversion to be economically feasible.





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This research was supported in part by the Ogallala Aquifer Program, a consortium of the USDA Agricultural Research Service, Kansas State University, Texas A&M AgriLife Research, Texas A&M AgriLife Extension Service, Texas Tech University, and West Texas A&M University.

Introduction

The Ogallala Aquifer is the primary source of water for irrigated agricultural production in the Texas High Plains. However, the aquifer is undergoing continuing depletion as pumping far exceeds the slow rate of recharge. New irrigation technologies have increased water use efficiency for many producers in the region. The introduction of low pressure center pivot technology increased application efficiency by approximately 30 percent or more over furrow irrigation. Currently, the most efficient center pivot system is low energy precision application (LEPA) with potential application efficiency of approximately 95 percent. The overall, most water-efficient irrigation system available is subsurface drip irrigation (SDI) with potential application efficiency of 97 percent.

While advancements in irrigation technology have increased water use efficiency, producers can be reluctant to convert to an even more efficient irrigation system when the initial investment costs are high. In addition, the decision making process can be complicated. Producers must evaluate several factors when making their decision including financing, crop mix, energy prices, energy sources available, commodity prices, labor availability, economies of scale, water availability, the system's application efficiency, the operating pressure of the design, crop rotations, the management requirements, and the depth from which the water must be pumped, or pumping lift.

Although the initial cost may be high, installing an irrigation system can positively impact the appraisal value of land. A center pivot system often stays with the land upon sale due to the challenges of moving the system. In the case of SDI, the majority of the system is attached to the land and simply cannot be moved, making the system a permanent fixture to the land. Thus, installing either of these systems can benefit the landowner through increased land value. In addition, irrigation systems may impact the cash rental rate for irrigated cropland. A report by Taylor and Tsoodle (2015) concluded that on average across the state of Kansas, the cash rental rate was approximately $32 per acre higher if the landowner owns the pivot compared to the tenant owning the pivot. Thus, a tenant or landowner may choose to purchase a pivot in order to have a more favorable cash rental or crop share agreement.

The cost of a SDI irrigation system may be off-set by a decrease in pumping costs from a greater application efficiency and/or higher revenue from yield and quality increases that may occur due to a change in application frequency. A study was previously conducted on the costs and benefits of different types of irrigation systems used in Texas in order to assist producers in making decisions about irrigation systems (Amosson et al., 2011). Results suggest that a conversion from LEPA to SDI is not economically feasible due to the high investment cost relative to the small gain in application efficiency. However, the initial study did not assume any associated change in crop yields with the conversion, and existing literature provides varying degrees to which SDI might increase yields (Bordovsky, Lyle, and Segarra, 2000). In this evaluative effort, the decreased variable costs of pumping will be considered along with the increase in yield that would be necessary to make SDI economically feasible.

The overall objective of this study is to estimate the economic feasibility of replacing LEPA irrigation with SDI for a square quarter section of land (160 acres). Specifically, this study estimates the changes in net investment, variable costs, and total costs related to the conversion of irrigation systems. Then, these costs are to be used to estimate the necessary increase in yields with a SDI system under alternative crop scenarios to make the conversion economically feasible. In addition, sensitivity analyses are conducted to account for varying discount rates and system costs.

Initial Cost Study of Irrigation Systems

To assist producers making decisions about irrigation systems, Texas A&M System researchers studied the costs and benefits of five types of irrigation systems commonly used in Texas: furrow (or surface flow) irrigation; mid-elevation spray application (MESA) center pivot; low elevation spray application (LESA) center pivot; low energy precision application (LEPA) center pivot; and subsurface drip irrigation (SDI).The study focused on the approximate costs, both gross and net, of buying and operating each system as well as each system's potential benefits for improving water application efficiency and reducing field operations. The study also looked at the effect of economies of size on center pivots and the impact of other major factors such as fuel prices, pumping lift, and labor costs. Lastly the study showed the economics of improving natural gas engine efficiency as well as natural gas versus electric powered irrigation (Amosson et al., 2011).

Characteristics of LEPA and SDI Irrigation Systems

The two types of irrigation systems compared in this study have varying designs, costs, management requirements, advantages, and disadvantages. Producers should evaluate these systems in light of the characteristics and requirements specific to their farming/ranching operations.

LEPA center pivot systems discharge water generally between alternate crop rows planted in a circle. Water is applied either with a bubble applicator within 12 to 18 inches above ground level or with drag socks or hoses that release water onto the ground. When spray application is needed (for chemigation applications or to improve soil surface moisture for crop germination for instance), drag socks and hose adapters can be easily removed from the applicator and replaced with a spray applicator. Another product, the LEPA "quad" applicator, delivers a bubble water pattern that can be reset to an optional spray pattern for germination and other in-field adjustment applications as needed. With a LEPA system, the water application is precise and concentrated reducing surface wetting, and hence reducing evaporation losses. However, the instantaneous application rate exceeds the soils intake characteristic thereby requiring the use of furrow dikes. LEPA is generally not suitable for sloping fields due to increased risk of runoff losses. LEPA can be used in circles or in straight rows. It is especially beneficial for low-profile crops such as cotton and peanuts. This irrigation system is more common in areas with limited water supplies. A disadvantage of LEPA is that it requires more planning and management, especially for crops in clay soils that infiltrate water more slowly.

With SDI, drip lines are placed from 6 to 12 inches below the soil surface with the depth depending on the crop, soil type, and tillage practices. Drip lines (or tape) typically include built-in emitters at optional designed spacings and emitter flow rates. Selection of spacing and flow rate of the emitters depend on the amount of water required by the crop. Drip lines should be installed no more than two row widths apart; most SDI systems in the region include tape lateral spacing under alternate furrows or under every planted row (row spacings typically vary from 30 to 40 inches, depending upon the cropping system). The amount of system water capacity available dictates the system's design, control, and management. Like the LEPA center pivot, SDI is a low-pressure, low-volume irrigation system.

The advantages of a subsurface drip system include properties that make it convenient and efficient way to supply water directly in the soil along individual crop rows and surrounding individual plant roots. It saves money by using water and labor efficiently. SDI effectively delivers very small amounts of water daily, which can minimize leaching of soluble chemicals and may increase yields.

There are some notable disadvantages to SDI. During dry spring periods, an SDI system may be unable to deliver enough water to germinate the crop, and more water than needed must be applied for the crop, resulting in deep-percolation losses. Also, the system must be designed and installed accurately. Also, if the system is not managed or maintained properly, much water can be lost to deep percolation and leaks can be a significant issue. Rodent issues can also be significant.

Data and Methods

This study focused on the conversion costs from a LEPA to SDI irrigation system in the Texas Northern High Plains Region, Figure 1. In estimating costs, it was assumed that each irrigation system was installed on a square quarter section of land (160 acres) and that the terrain and soil type did not affect the efficiency of the irrigation system. The LEPA system considered in this study consisted of 145 drops spaced 10 feet apart while the SDI system had emitter lines spaced five feet apart. In this study, a cost/benefit analysis was conducted where the net change in costs of converting from LEPA to SDI were used to gauge the increase in revenue that would be necessary to make the conversion economically feasible.

The change in total costs was estimated using both the net investment costs and total variable costs over the 25-year life of each system. First, the gross investment and variable costs of the two systems were obtained (Amosson et al., 2011) and updated to current dollars using the Producer Price Index from the Bureau of Labor Statistics (2014). The costs for the well, pump, and engines were assumed to be the same for each irrigation system and were not included in the investment cost. The gross investment was $599.46 per acre for a LEPA system, while investment was more than double for the SDI system at $1,293.81 per acre, Table 1.

The net investment was calculated taking into consideration tax savings, future salvage value, and the opportunity cost of the investment. This allows for the comparison of net costs of irrigation systems across multiple years. The salvage value of each system was estimated to be 20 percent of the gross investment. Tax savings were calculated using a tax life of seven years and a marginal tax rate of 15 percent.

Three alternative discount rates of zero, three, and six percent were used to obtain present value and then compared to see how alternative rates affected the net investment of each system. Discount rates will vary by producer and can depend on whether the system was fully paid at the time of purchase or if borrowed funds were necessary and the interest rate applied. The discount rate also depends upon the individual producer's perception of risk or uncertainty of future cash availability. A higher discount rate results in a higher net investment cost for both systems over the 25-year useful life. The net investment was $407.64 per acre for LEPA and $879.79 per acre for SDI under a zero percent discount rate and $504.01 and 1,087.79 per acre for LEPA and SDI, respectively, under a six percent discount rate, Table 1.

Four different crops were analyzed including corn, cotton, sorghum, and wheat, where corn represents a high water use crop, sorghum and wheat represent intermediate water use crops, and cotton represents a low water use crop. Variable costs include fuel, lubrication, maintenance, repairs, and labor. The variable pumping costs in dollars per acre-inch of water pumped for each irrigation system at a 350-foot pumping lift are shown in Table 2. The variable costs for a LEPA system are slightly higher than the variable costs for SDI. The main difference between the irrigation systems is the increased efficiency with SDI.

The annual variable costs per acre were calculated by multiplying the variable cost estimates per acre-inch by the number of acre-inches of water required for each system and crop (Amosson et al., 2011), Table 3. Then, the difference in net investment was combined with the change in total variable costs over the 25-year life of the system to obtain the total net difference in costs between the two systems, Table 4.

The higher cost of a SDI irrigation system must be offset by a decrease in pumping costs from the increased application efficiency and yield increases that may occur due to a change in application frequency in order for the system to be economically feasible. Increased application frequency can decrease plant stress, which is particularly important in a limited irrigation situation. A five-year average of crop prices (Texas A&M AgriLife Extension Service, 2014) was obtained and used in conjunction with harvesting costs (Texas A&M AgriLife Extension Service, 2013) to calculate the effective change in revenue per unit increase in yield, Table 5.

The change in total costs between the two systems and the effective change in revenue per unit increase in yield were used to determine the increase in yield needed to make conversion to SDI economically feasible. These yield levels were then compared with a five-year historical yield (National Agricultural Statistics Service, 2014), Table 5, to determine the relative percentage increase needed.

The investment cost of each system is dependent upon many factors including specifications/modifications to a standard system from a particular customer, inflation of purchase price due to increased material costs, and specific location factors such as soil type. For SDI, drip line spacing and associated labor costs, as well as filtration and chemigation injection equipment requirements (a function of the water quality) can have a large impact on the initial investment cost. Thus, a sensitivity analysis was conducted in which the initial investment of both systems was increased by 10 percent, 20 percent, and 30 percent over the baseline investment cost. This sensitivity analysis was conducted to give an indication of what the increase in yield would need to be if investment costs were higher than expected under the standard or average situation.

Results

Results indicate that at a zero percent discount rate, an additional 69 bushels per acre (37 percent increase) for corn would be needed in order to payback the additional costs of an SDI system in one year, Figure 2. Over a longer term of 10 years, however, this would be an increase of seven bushels per acre per year, which is an increase of four percent per year. Cotton requires an additional 510 pounds per acre (52 percent increase) if the payback is one year or 51 pounds (five percent more per year) for a payback of 10 years. Sorghum yields would need to almost double (93 percent increase or 85 more bushels per acre) in order to payback the SDI system in one year or increase by nine percent per year if the payback period is 10 years. Wheat requires the largest percentage yield increase over historical yields with an additional 68 bushels or 155 percent increase for a payback of one year. A longer payback period would still require a substantial increase in yields at 16 percent more per year for 10 years.

The higher discount rates of three and six percent result in a higher increase in yields over the historical average in order for the SDI system to be feasible. For corn and cotton, yields would have to be more than 12 percent higher under the three percent discount rate and more than 20 percent higher under the six percent discount rate than the zero percent discount rate scenario, Figures 3 and 4. The yield increase for sorghum would need to be 27 percent and 44 percent above historical yields with wheat needing to be 45 percent and 74 percent higher under the three and six percent discount rates, respectively, than the zero percent discount rate scenario, Figures 3 and 4.

The results of the sensitivity analysis for an increase of 10, 20, and 30 percent over the baseline scenario investment costs for both systems are shown in Table 6. The results indicate the degree that yields will need to increase to justify the additional investment cost of an SDI system. The increase in yields needed for a one year payback period ranges from a 42 percent increase in corn yields with 10 percent higher investment costs to a 212 percent increase in wheat yields with 30 percent higher investment costs. Thus, producers should closely evaluate their individual situation and closely consider the estimated investment cost before making the decision to convert from LEPA to SDI.

Summary

Previous studies have shown that compared to center pivot LEPA systems, savings in pumping costs under SDI is not enough to off-set the increased investment cost regardless of the crop because of the relatively small gains in application efficiency. However, producers may benefit from potential yield increases because of the ability to apply more frequent applications, assuming average spring conditions and well managed and maintained SDI systems. The effect of savings in pumping costs coupled with possible yield increases may be enough to justify the additional SDI investment costs over time.

The overall objective of this study was to estimate the necessary increase in yields with a SDI system under alternative crop scenarios to make the conversion economically feasible. In addition, sensitivity analyses were conducted to account for varying discount rates and system costs. The magnitude of an increase in yield needed with conversion to SDI varies greatly by crop and discount rate. Results of this study indicate that corn would require the smallest percentage increase in yield (relative to the historical average), followed by cotton, sorghum, and wheat. Thus, the adoption of an SDI system is more feasible for relatively higher-value crops such as corn and cotton versus lower-value crops.

Alternative discount rates were used to evaluate the effect on the study results. In general, a larger discount rate would require a higher yield increase over historical yields in comparison with a discount rate of zero. A sensitivity analysis was conducted in order to account for situations with higher investment costs. The results of this analysis indicate the impact of higher investment costs on necessary yield increases for an SDI system.

There are many factors that producers should closely evaluate when deciding on an irrigation system. This analysis is based upon average information for producers in the Texas Panhandle and it should be noted that this may not accurately reflect an individual producer's circumstance. Producers should consider how their operation compares with the scenarios and assumptions made in this study. Future research should be conducted which addresses varying levels of crop prices, application efficiencies, government assistance programs, and pumping limits.

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Table 1. Investment costs of LEPA and SDI irrigation systems ($/acre)[1].

System	Gross Investment	Net Investment (0% Discount Rate)	Net Investment (3% Discount Rate)	Net Investment (6% Discount Rate)
LEPA	$599.46	$407.64	$470.76	$504.01
SDI	$1,293.81	$879.79	$1,016.03	$1,087.79

[1] Assumes a marginal tax rate of 15%, a useful life of 25 years, and a salvage value of 20% of the gross investment.

Table 2. Total Variable Costs of a LEPA and SDI system ($/ac-in).

System	Corn	Cotton	Sorghum	Wheat
LEPA	$11.63	$12.47	$11.87	$11.87
SDI	$11.62	$12.44	$11.86	$11.86

Table 3. Water use by system and crop (ac-in/acre).

System	Corn	Cotton	Sorghum	Wheat
LEPA (95% efficient)	18.53	7.41	12.97	12.97
SDI (97% efficient)	18.14	7.26	12.70	12.70

Table 4. Difference in total costs (net investment and variable costs) between LEPA and SDI irrigation over the 25-year life of the system ($/acre).

Discount Rate:	Corn	Cotton	Sorghum	Wheat
0%	$356.17	$418.63	$389.38	$389.38
3%	$464.48	$507.99	$487.61	$487.61
6%	$524.47	$556.42	$541.46	$541.46

Table 5. Average prices, harvest costs, and yields for alternative crops, 2009-2013.

Crop	Unit	Price ($/unit)	Harvest Cost ($/unit)	Yield (units)
Corn	bu	5.44	0.43	207
Cotton[1]	lb	0.88	0.12	1,054
Sorghum	bu	4.82	0.42	91
Wheat	bu	6.42	0.59	47

[1] Price and harvest cost was modified to include cotton seed.

Table 6. Percentage yield increase for 10%, 20%, and 30% higher investment costs than the baseline scenario (1-year payback period).

% Increase in Investment Cost	% Yield Increase Over Historical			
	Corn (bu)	Cotton (lbs)	Sorghum (bu)	Wheat (bu)
0% Baseline	36.74%	51.50%	93.29%	155.32%
10%	41.61%	57.31%	104.61%	174.16%
20%	46.48%	63.12%	115.92%	192.99%
30%	51.35%	68.93%	127.23%	211.82%

Figure 1. Texas Northern High Plains study area.

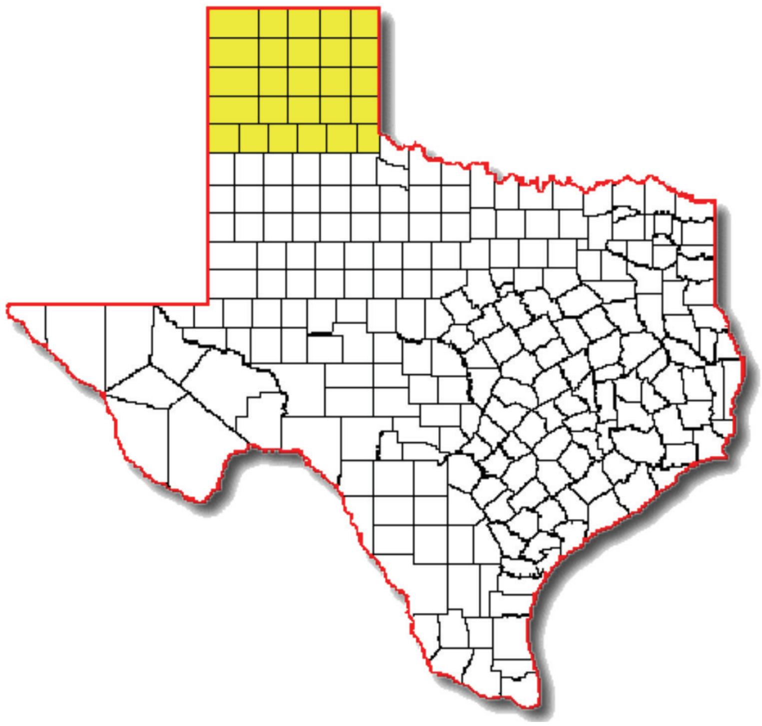

Figure 2. Annual yield improvement needed (compared to historical) for various payback years, 0% discount rate.

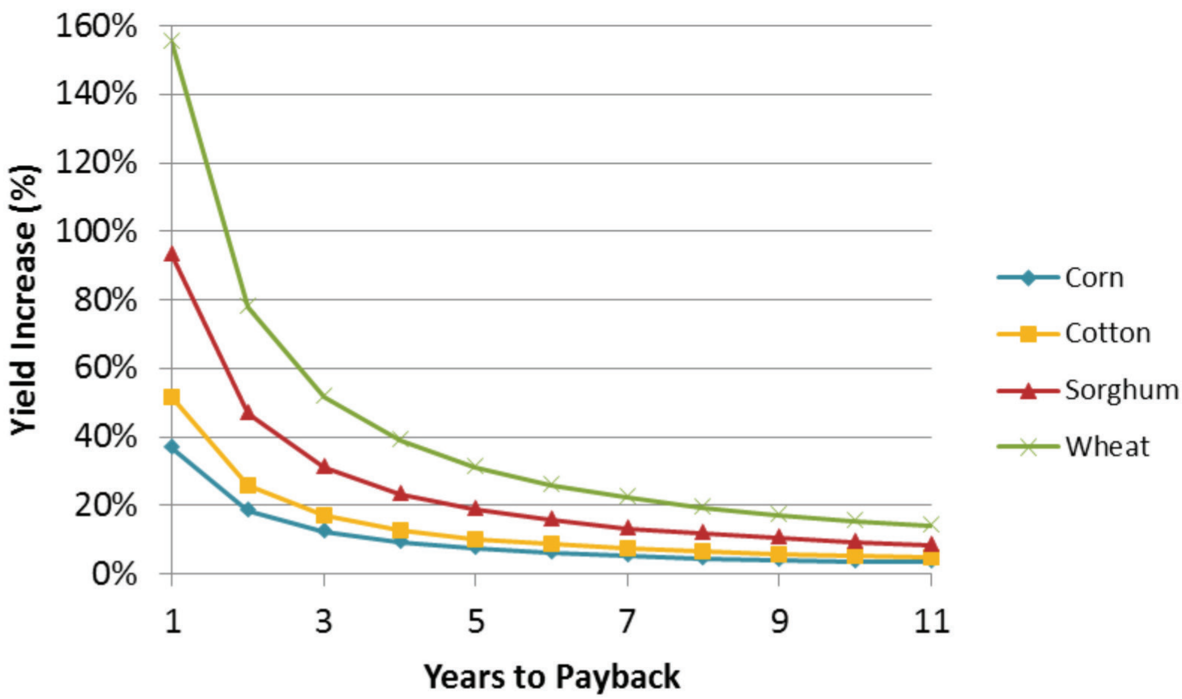

Figure 3. Annual yield improvement needed (compared to historical) for various payback years, 3% discount rate.

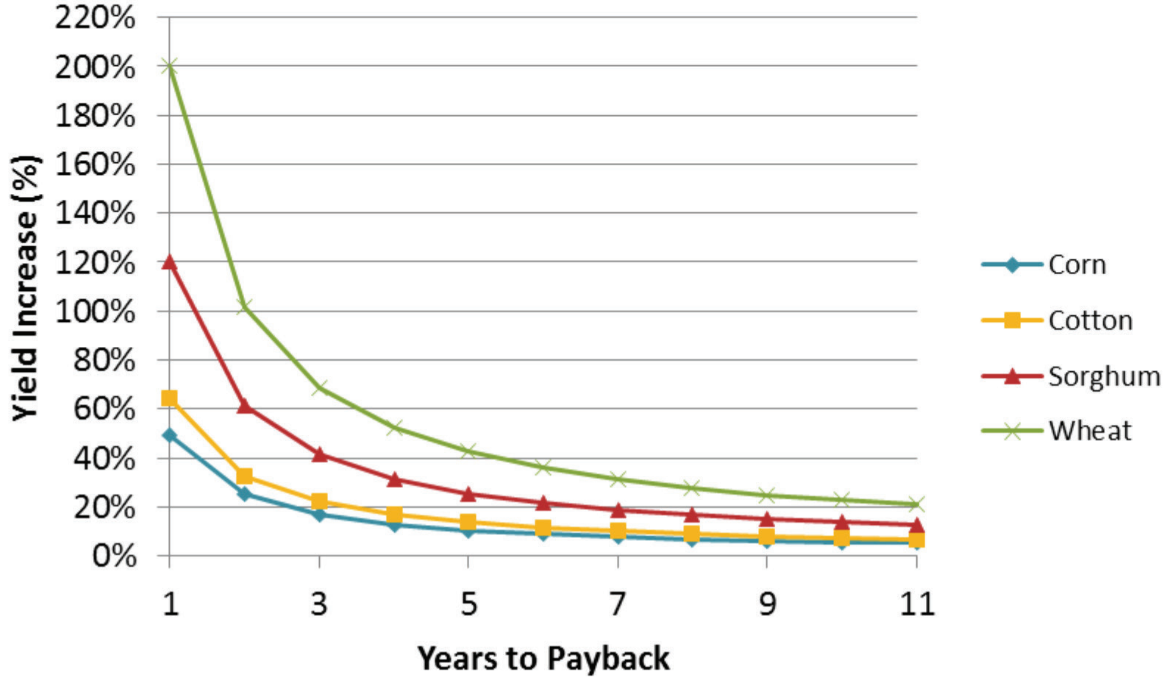

Figure 4. Annual yield improvement needed (compared to historical) for various payback years, 6% discount rate.