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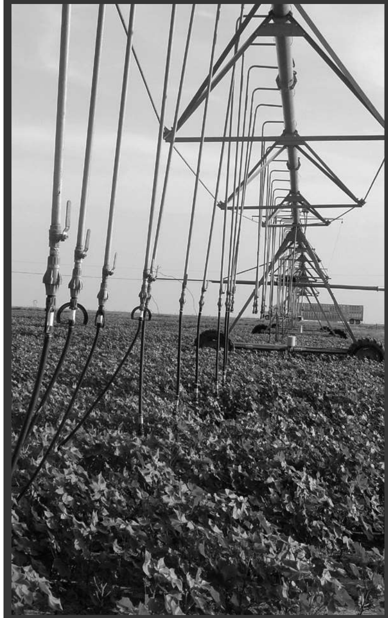

# Economics of Irrigation Systems

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# Contents

# Introduction

Irrigation can improve crop production, reduce yield variability, and increase profits. But choosing and buying an irrigation system are both expensive and complex.

When considering investing in an irrigation system, farmers must keep in mind several major factors: financing, crop mix, energy prices, energy sources, commodity prices, labor availability, economies of scale, the availability of water, savings in field operations, the system's application efficiency, the operating pressure of the design, and the depth from which the water must be pumped, or pumping lift.

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) 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
- Each system's potential benefits for improving water application efficiency and reducing field operations
- The effect of economies of size on center pivots
- The impact of other major factors such as fuel prices, pumping lift, and labor costs
- Economics of improving natural gas engine efficiency
- Natural gas versus electric powered irrigation

The costs of buying and operating an irrigation system may vary among farms because of differences in individual farming/ranching operations. Before changing management strategies, producers should compare their operations closely to those in the study.

For the study, it was assumed that each irrigation system was installed on a "square" quarter section of land (160 acres) or in the case of a half-mile pivot a square section (640 acres). It was assumed that the terrain and soil type did not affect the feasibility of the irrigation system.

## Application efficiency

Not all of the water irrigated is used by the crop. The percentage of irrigation water used by a crop is called the system application efficiency. To determine the amount of water required to irrigate crops using the different systems, farmers must know and be able to compare the application efficiency of each system.

Application efficiency can vary among systems because of:

- Differences in design, maintenance, and management of the systems
- Environmental factors such as soil type, stage of crop development, time of year, and climatic conditions
- The availability of water and its potential value for other uses
- Economic factors such as commodity and fuel prices

For the five systems studied, the application efficiency ranged from 60 to 97 percent. Those with the highest application efficiencies tended to have the lowest pumping costs. Of the five irrigation systems, the least efficient was the furrow system; the most efficient was the subsurface drip irrigation system.

An efficiency index was calculated to show the amount of water (in inches per acre) that each system would have to additionally apply to be as effective as the LESA system (Table 1).

**Table 1. Basic assumptions for five irrigation distribution systems**

| Irrigation system | Operating pressure (psi)[1] | Application efficiency (%) | Efficiency index | Acres irrigated |
|---|---|---|---|---|
| Furrow | 10 | 60 | 1.47 | 160 |
| Mid-elevation spray application (MESA) | 25 | 78 | 1.13 | 125 |
| Low elevation spray application (LESA) | 15 | 88 | 1.00 | 125 |
| Low energy precision application (LEPA) | 15 | 95 | 0.93 | 125 |
| Subsurface drip irrigation (SDI) | 15 | 97 | 0.91 | 160 |

[1] psi = pounds of pressure per square inch of water

The calculations were made using the LESA center pivot system as a base. It was assumed that applying the same amount of "effective" water would produce the same crop yield. Therefore, according to the index, a subsurface drip system would need only 91 percent of the water used by the LESA system to be just as effective. The furrow system would require 47 percent more water than the LESA system to be equally effective.

When evaluating the additional costs of the more efficient systems, farmers can consider the reduced irrigation that will be needed for each system.

## Operating pressure

A system's operating pressure affects the cost of pumping water. Higher pressure makes irrigation more expensive. Of the five systems studied:

- Furrow system usually had an operating pressure of 10 pounds per square inch (psi).

- LESA, LEPA, and SDI had an intermediate operating pressure of 15 psi, depending on the flow rate.
- MESA center pivot systems required a higher pressure of 25 psi.

Table 1 lists the operating pressures that were used to compare the pumping cost for each system. To function properly, each irrigation system must maintain adequate and consistent operating pressure. Water flow (measured in gallons per minute, or GPM) dictates the operating pressure that must be maintained for a system's design. As GPM drops, growers must close furrow gates, renozzle center pivots, and reduce the number of emitter lines to make the system work properly.

# Irrigation Systems

The five irrigation systems studied had 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.

## Furrow irrigation

Furrow irrigation delivers water from an irrigation well via an underground supply pipeline, to which gated pipe is connected. This configuration is prevalent throughout the Texas High Plains. The water flows by gravity on the surface through the furrows between crop rows (Fig. 1).

**Figure 1. Furrow irrigation on cotton.**

The gated pipe must be moved manually from one irrigation set to the next one that accommodates the well GPM, usually every 12 hours. In the study, two irrigation sets of gated pipe were used to allow the water flow to be changed without interruption.

Polypipe can be used instead of aluminum or PVC gated pipe. Normally, polypipe is not moved. Appropriate lengths are cut, plugged, and connected to underground pipeline risers. Like gated pipes, furrow gates deliver water between crop rows (Fig. 2). The limitation of polypipe is that it is much less durable and is usually replaced every 1 to 2 years.

**Figure 2. Furrow polypipe on cotton.**

With good planning, land preparation, and management, furrow irrigation can achieve 60 percent water application efficiency (Table 1). That is, 60 percent of the water irrigated is used by the crop. The rest is generally lost to deep percolation below the crop root zone. Furrow systems are best used in fine-textured soils that have low infiltration rates.

For highest crop production, water should be supplied simultaneously and uniformly to all plants in the field. To make the application more uniform, farmers can consider laser-leveling fields, adjusting gates, and modifying the shape, spacing, or length of the furrow.

Disadvantages of furrow irrigation include:

- It usually requires additional tillage preparation and labor, especially if the terrain varies in elevation.
- It can cause some environmental problems, such as soil erosion, sediment transport, loss of crop nutrients, deep percolation of water, and movement of dissolved chemicals into groundwater.
- Terrain variations can cause the water to be distributed unevenly, reducing crop growth and lowering overall crop yield.
- Furrow irrigation usually applies water at higher increments than do center pivot or subsurface drip systems.

To address these problems, farmers can take remedial measures such as laser leveling, planting filter strips, mechanical straw mulching, reducing tillage, changing furrow design, and installing sediment ponds with tail water pump-back features.

## Mid-elevation spray application (MESA) center pivot

Mid-elevation spray application center pivots have water sprayer heads positioned about midway between the mainline and ground surface.

The quarter-mile system considered in this study consisted of 145 drops spaced 10 feet apart. Polydrops (or optional flexible drop hose) were attached to the mainline gooseneck or furrow arm and extended down to the water applicator (Fig. 3).

In MESA systems, water is applied above the primary crop canopy, even on tall crops such as corn and sugarcane. Weights and flexible drop hoses should be used to

**Figure 3. MESA center pivot, half-mile system.**

reduce water losses and improve distribution, particularly in windy areas such as the Texas High Plains.

The nozzle pressure for MESA varies according to the type of water applicator and the pad arrangement selected. Although some applicators require an operating pressure of 20 to 30 psi, improved designs require only 6 to 10 psi for conventional 8- to 10-foot mainline outlet and drop spacing. These applicators are now common and perform well. The operating pressure can be lowered to 6 psi or less if the sprayer heads are positioned 60 to 80 inches apart.

A disadvantage of mid-elevation spray application is that it is subject to water losses via the air and through evaporation from the crop canopy and soil surface. Research has shown that when using above-canopy irrigation for corn production, 10 to 12 percent of the water applied is lost from evaporation from the foliage. Field comparisons showed a total water loss (air, foliage, and soil) of 20 to 25 percent from MESA center pivot irrigation systems where applicators were set above the crop canopy.

The research study found that the water application efficiency averaged 78 percent for MESA center pivot systems (Table 1).

## Low elevation spray application (LESA) center pivot

In low elevation spray application center pivot systems, water applicators are positioned 12 to 18 inches above ground level or high enough to allow space for wheel tracking (Fig. 4). Each applicator is attached to a flexible drop hose, which is connected to a gooseneck or furrow arm on the mainline.

Figure 4. LESA center pivot on cotton.

Weights are positioned immediately upstream from the pressure regulator and/or the applicator. They help stabilize the applicator in wind and allow it to work through plants in straight crop rows. It is best to maintain nozzle pressure as low as 6 psi with the correct water applicator.

The optimal spacing for LESA drops should be no wider than 80 inches. If installed and managed properly, LESA drops can be spaced on conventional 8- to 10-foot MESA spacing.

Corn crops should be planted in circular rows; the water should be applied beneath the primary foliage. Some growers have used LESA successfully in straight corn rows at conventional outlet spacing by using a flat, coarse, grooved pad that allows the water to spray horizontally. The coarser (fewer grooves) pads generally result in the least evaporation loss because of the larger droplet sizes, but they can cause in soil dispersion with some soils.

Grain sorghum and soybean crops can also be planted in straight rows. With wheat, the foliage may cause the water distribution to be significantly uneven if the nozzles are within the crop's dense canopy. To improve water distribution, growers may need to temporarily swing the drop hose and thus the applicator over the truss rod, effectively raising the nozzle above or near the top of the canopy.

LESA center pivots generally wet less foliage, especially for a crop planted in a circle. Less water is lost to evaporation. The water application efficiency for LESA usually averages 85 to 90 percent (Table 1), but it may be lower in open, lower profile crops such as cotton and peanuts, or in broadcast crops such as wheat or alfalfa.

When the drops are spaced no more than 80 inches apart, LESA center pivots can easily be converted to LEPA with an applicator adapter that includes a connection for attaching a drag sock or hose.

## Low energy precision application (LEPA) center pivot

Low energy precision application center pivot systems discharge water between alternate crop rows planted in a circle. Water is applied either with a bubble applicator 12 to 18 inches above ground level or with drag socks or hoses that release water on the ground.

Drag socks help reduce furrow erosion; double-ended socks are designed to protect and maintain the furrow dikes (Fig. 5). When needed, drag socks and hose adapters can be easily removed from the applicator and replaced with a spray nozzle.

Figure 5. LEPA center pivot with a drag sock.

Figure 6. LEPA center pivot with a bubble applicator on corn.

Another product, the LEPA "quad" applicator, delivers a bubble water pattern (Fig. 6) that can be reset to an optional spray pattern for germination and other in-field adjustments needed.

LEPA applicators are usually placed 60 to 80 inches apart, corresponding to twice the row spacing. Thus, one row is wet and one row is dry. Dry middles allow more rainfall to be stored. When the crop is planted in a circle, the applicators are arranged to maintain a dry row for the pivot wheels.

Research and field tests show that crop production is the same whether water is applied in every furrow or only in alternate furrows. The field trials indicated that crops use 95 percent of the irrigation water pumped through a LEPA system (Table 1). The water application is precise and concentrated.

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.

## Subsurface drip irrigation (SDI)

In subsurface drip irrigation, drip tubes are placed from 6 to 12 inches below the soil surface, the depth depending on the crop, soil type, and tillage practices.

Drip tubes typically include built-in emitters at optional spacings. The spacing and flow rate of the emitters depend on the amount of water required by the crop. Drip tubes should be installed no more than two row widths apart.

**Figures 7a and b. Subsurface drip irrigation.**

The amount of water available dictates the system's design, control, and management. Like the LEPA center pivot, SDI is a low-pressure, low-volume irrigation system (Figs. 7a and b).

Considered the most water-efficient system available, SDI has an application efficiency of 97 percent (Table 1). The advantages of a subsurface drip system include:

- It is a 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.
- It can effectively deliver very small amounts of water daily, which can save energy, increase yields, and minimize leaching of soluble chemicals.

Subsurface drip systems have these disadvantages:

- They require intensive management.
- During dry springs, 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.
- The system must be designed and installed accurately. If the system is not managed properly, much water can be lost to deep percolation.

## Evaluating irrigation systems

Evaluating the feasibility of investing in a new irrigation system can be very complicated because many factors are involved. However, once all the factors are taken into consideration, the methodology in making the decision is relatively simple.

Growers should first estimate the gross investment cost, which is the amount of money required to buy the system. Next, estimate the "true" economic cost, or the net investment. Net investment takes into account tax savings, future salvage value, and the opportunity cost (what the money could be earning if invested in the next best alternative) of the investment.

Each irrigation system has a combination of annual benefits that reduce costs and/or improve efficiency. The benefits may include decreased pumping, labor, and field operations. These benefits may offset the cost of adopting the system.

Because a dollar today is worth more than a dollar 5 years from now, all annual costs and benefits must be discounted to today's dollars. This will allow you to directly compare the costs and benefits of irrigation systems both initially and across multiple years.

## Investment cost of irrigation systems

The investment costs for the irrigation systems studied are listed in Table 2. 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 for each quarter-section system (160 acres) ranged from $208.56 per acre for furrow to $1,200.00 for subsurface drip irrigation with emitter lines

**Table 2. Investment costs of alternative irrigation systems**

| Distribution system | Gross investment ($/acre) | Net investment[1] ($/acre) | Net investment[2] ($/acre) |
|---|---|---|---|
| Furrow | 208.56 | 183.62 | 161.99 |
| Center pivot, quarter mile | 556.00 | 467.57 | 413.28 |
| Center pivot, half mile | 338.00 | 284.24 | 251.24 |
| Subsurface drip irrigation | 1,200.00 | 1,009.13 | 891.97 |

[1] Assumes a marginal tax rate of 15 percent and discount rate of 6 percent

[2] Assumes a marginal tax rate of 28 percent and discount rate of 6 percent

Salvage values and useful system life are in the Appendix, Table A2.

spaced 5 feet apart. The gross investment for quarter-mile center pivot system is $556.00 per acre.

The total investment costs for each irrigation system, including well, pump, and engine for five pumping lifts, are provided in the Appendix, Table A1.

There are definite economies of scale associated with center pivot systems. You can substantially reduce the investment cost of a center pivot irrigation system by increasing the length of the pivot. Using a half-mile center pivot rather than four quarter-mile systems reduces the gross investment by 40 percent, or $218.00 per acre (from $556.00 to $338.00), as shown in Table 2. In addition, the corners become more functional for farming increasing from 8 to 40 acres.

To calculate the net investment, subtract the discounted salvage value and the tax savings associated with a new system from the purchase price of the distribution system. By accounting for discounted tax savings and salvage value, producers can get a true comparison of what they would pay for each system.

The net investments for the different systems vary significantly less than the gross investments. For example, the difference in net investment between a quarter-mile center pivot and furrow is $283.95 per acre ($467.57 – $183.62), given a 15 percent tax and 6 percent discount rate. The net investment for a subsurface drip irrigation system, $1,009.13 per acre, is substantially less than the gross investment of $1,200.00 per acre (Table 2).

The economic feasibility of a new irrigation system can be affected by the marginal tax rate. For example, if a producer's marginal tax rate is 28 percent instead of 15 percent, the net investment in subsurface drip is reduced by $117.16 (from $1,009.13 to $891.97) per acre; the net investment in furrow is reduced by $21.63 (from $183.62 to $161.99) per acre.

Therefore, all systems become more feasible at the higher tax rate. The most expensive system is affected the most by the marginal tax rate; the least expensive system is affected the least ($117.16 versus $21.63 per acre).

## Estimated annual operating expenses

In the study, annual operating expenses—including both fixed and variable costs—were estimated for each system per acre-inch of water pumped. These expenses per acre were based on the application efficiency of each system to apply the equivalent amount of water to achieve the same crop yield (Table 3).

**Table 3. Water pumped for three crop scenarios and five irrigation systems in Texas**

| Irrigation system | Application efficiency (%) | Application efficiency index | High water use (in./ac) | Intermediate water use (in./ac) | Low water use (in./ac) |
|---|---|---|---|---|---|
| Furrow | 60 | 1.47 | 29.33 | 20.53 | 11.73 |
| MESA | 78 | 1.13 | 22.56 | 15.79 | 9.03 |
| LESA | 88 | 1.00 | 20.00 | 14.00 | 8.00 |
| LEPA | 95 | 0.93 | 18.53 | 12.97 | 7.41 |
| SDI | 97 | 0.91 | 18.14 | 12.70 | 7.26 |

The annual pumping costs per acre were calculated by multiplying the total operating estimates per acre-inch by the number of acre-inches of water required for each system:

Total operating cost per acre-inch × Number of acre-inches of water required for the irrigation system = Annual pumping costs per acre

### Assumptions and crop scenarios

To calculate operating costs, researchers assumed three crop scenarios: high water use (corn), intermediate water use (sorghum/soybeans), and low water use (cotton).

For each crop scenario, the amount of water needed to be pumped was estimated by multiplying the water required by the LESA center pivot times the application efficiency index for each irrigation system. Therefore, the effective amount of water pumped would remain constant for all systems.

Water required by the LESA center pivot × Application efficiency index for the irrigation system = Amount of water required for the irrigation system

The application efficiency index for each system was calculated by dividing the LESA application efficiency (which is 0.88) by the application efficiency of that system.

For example, the application efficiency index for furrow is 1.47 (0.88 ÷ 0.60) and 0.93 for LEPA (0.88 ÷ 0.95). Therefore, if 14 inches per acre are pumped through the LESA center pivot system, a furrow system would require 20.53 inches per acre of water (14 × 1.47) to apply the same effective amount of water to the crop at the intermediate water use level (Table 3).

### Fixed operating costs

The fixed cost for operating each system includes the annual depreciation, taxes, insurance, and interest charges associated with an investment. The straight-line method was used to calculate depreciation.

Taxes were calculated at 1 percent of the assessed value using a tax assessment ratio of 0.20. Insurance was calculated as 0.60 percent of the purchase value. Interest was assumed to be 6 percent per year. The operational life of each irrigation system was assumed to be 25 years (Appendix Table 2A).

Table 4 lists the fixed costs in dollars per acre-inch of water pumped for the intermediate water-use crop scenario and 350-foot pumping lift for each system. This cost ranged from $1.10 for furrow to $6.05 for subsurface drip. The fixed cost per acre-inch for LESA center pivot is estimated to be $2.54, including $1.27 for depreciation, $0.08 taxes, $0.24 insurance, and $0.95 interest.

The assumptions used in the fixed-cost calculations are presented in the Appendix, Table A3.

## Variable pumping costs

Variable costs include fuel, lubrication, maintenance, repairs, and labor. Fuel costs are based on natural gas priced at $6.00 per thousand cubic feet (MCF). Lubrication, maintenance, and repairs are assumed to be 65 percent of the fuel cost. The labor cost to operate the well, pump, engine, and irrigation system was assessed at $10.30 per hour.

The variable pumping costs in dollars per acre-inch of water pumped for the five irrigation systems at a 350-foot pumping lift are shown in Table 4 for each system. Variable cost estimates by system and lift are given in the Appendix, Tables A4 through A6.

**Table 4. Fixed and variable pumping costs per acre-inch for the intermediate water-use scenario (sorghum/soybeans) at a 350-foot pumping lift for five irrigation systems**

| | ----------- $/ac-in. of water ----------- | | | | |
|---|---|---|---|---|---|
| Cost component/system | Furrow | MESA | LESA | LEPA | SDI |
| A. Fixed cost | | | | | |
| Depreciation | 0.41 | 1.13 | 1.27 | 1.37 | 3.02 |
| Taxes | 0.02 | 0.07 | 0.08 | 0.09 | 0.19 |
| Insurance | 0.06 | 0.21 | 0.24 | 0.26 | 0.57 |
| Interest charges | 0.61 | 0.85 | 0.95 | 1.03 | 2.27 |
| Total fixed costs | 1.10 | 2.26 | 2.54 | 2.75 | 6.05 |
| B. Variable costs | | | | | |
| Fuel costs | 6.04 | 6.55 | 6.22 | 6.22 | 6.22 |
| LMR[1] charges | 3.93 | 4.26 | 4.04 | 4.04 | 4.04 |
| Labor costs | 1.19 | 0.91 | 0.80 | 0.75 | 0.73 |
| Total variable costs | 11.16 | 11.72 | 11.06 | 11.01 | 10.99 |
| Total fixed and variable cost (A+B) | 12.26 | 13.98 | 13.60 | 13.76 | 17.04 |

[1] Lubrication, maintenance and repairs

The estimated total cost per acre-inch varied considerably among the systems evaluated. Furrow had the lowest total cost at $12.26 per acre-inch; subsurface drip had the highest cost at $17.04 per acre-inch. LESA, LEPA, and MESA center pivot systems ranged from $13.60 to $13.98 per acre-inch.

## Total pumping cost

To calculate the annual pumping cost in dollars per acre in each crop scenario, the total operating costs per acre-inch were multiplied by the number of acre-inches of water pumped.

For the intermediate water use scenario, LEPA center pivot had the lowest annual pumping cost, $178.45 (12.97 acre-inches × $13.76 per acre-inch), because of its high application efficiency. Conversely, furrow irrigation, which had the lowest pumping cost per acre-inch ($12.26), had the highest total annual pumping cost $251.79 (Table 5). This is because of its relatively low application efficiency, resulting in more water having to be pumped to apply the same effective amount.

**Table 5. Total pumping cost per acre using natural gas fuel at a 350-foot pumping lift for three crop scenarios and five irrigation systems**

| | ---------------------- $/ac ---------------------- | | |
|---|---|---|---|
| System/water use | High water use | Intermediate water use | Low water use |
| Furrow | 339.03 | 251.79 | 163.89 |
| MESA | 293.86 | 220.81 | 147.48 |
| LESA | 252.20 | 190.40 | 128.88 |
| LEPA | 235.31 | 178.45 | 121.31 |
| SDI | 272.35 | 216.41 | 160.51 |

## Savings from field operations and total annual irrigation

Center pivot and subsurface drip irrigation systems require fewer field operations than does furrow irrigation. For example, the field operations commonly used to produce corn under furrow irrigation include shredding, offset disking, chiseling, tandem disking, bedding, rod weeding, planting, and two cultivations.

For center pivot or subsurface drip irrigation, the number of field operations is generally reduced to shredding, offset disking, chiseling, planting, and one cultivation. This represents a reduction of four field operations. Assuming a cost of $11 per operation, the estimated savings are $33 per acre under conventional tillage.

The number of field operations performed or saved varies considerably, depending on the crop planted, cropping system, and growing conditions for a particular year. Corn

**Table 6. Savings in pumping cost and field operations using natural gas fuel at a 350-foot pumping lift for the intermediate water-use scenario when shifting from furrow to more efficient irrigation systems per acre**

| | ----------------------- $/ac ----------------------- | | |
|---|---|---|---|
| System | Savings in pumping cost | Savings from field operations | Annual irrigation savings |
| MESA | 30.97 | 33.00 | 63.97 |
| LESA | 61.39 | 33.00 | 94.39 |
| LEPA | 73.34 | 33.00 | 106.34 |
| SDI | 35.38 | 33.00 | 68.38 |

producers have estimated that from three to five field operations may be saved under center pivot or subsurface drip irrigation, amounting to $33 to $55 per acre. Typically, three field operations are eliminated for sorghum, soybeans, and cotton production, saving $33 per acre (Table 6).

## Cost/Benefit Analysis

Table 7 lists the net investment cost and benefits of adopting efficient irrigation technology at a 350-foot pumping lifts for high, intermediate, and low water-use crop scenarios. The benefits include the estimated savings from reduced pumping costs and field operations from the five more efficient systems compared to the least efficient system (furrow). The series of benefits accumulated over the life of irrigation equipment (25 years) is discounted at the rate of 6 percent to present value.

It is considered economically feasible to adopt an irrigation system technology when the change in expected benefits exceeds the net investment cost. Comparing the purchase of furrow system to a LEPA center pivot system reveals that LEPA requires an additional net investment of $283.95 ($467.57 – $183.62) per acre; however, the reduction in field operations and pumping costs would save $1,747.71 per acre under the assumption of high water use.

Even under low water use, adoption of LEPA is favorable, with expected gain in benefits of $966.22 per acre compared to the $283.95 per acre of additional investment.

Evaluating the conversion or replacement of an existing system from the data presented in Table 7 is more difficult. The expected benefits for each system as given in Table 7 will remain the same. However, a producer will need to estimate the cost of conversion, or the net investment of the "new" system adjusted for the salvage value of the present system, in order to evaluate its feasibility.

Several conclusions can be made from the results in Table 7:

- It appears that the water and/or field operation savings justify converting furrow to center pivots whenever physically possible.
- The lack of difference between the costs of center pivot suggests that producers should buy the system with the highest water application efficiency that works for their operation.
- Converting furrow to drip irrigation is not feasible under a low water-use scenario based on water and field operation savings.

The study did not address the potential yield increase of applying water to the crop more often or the ability to irrigate more acreage with the same amount of water because of the improved application effectiveness. These factors could affect drip irrigation feasibility, especially for high-value crops.

## Sensitivity Analysis

The major factors that influence pumping cost for irrigated crops are price of fuel, pumping lift, inches of water pumped, and labor wage rate. These factors affect the economic feasibility of alternative irrigation systems.

Below are analyses of the effects of varying fuel price, pumping lift, water pumped, and wage rate on irrigation costs for each irrigation system.

### Impact of fuel prices on pumping cost

The effect of fuel price on the grower's fuel costs was calculated for each of the five irrigation systems. The fuel costs were estimated using natural gas prices ranging from $4.00 to $14.00 per MCF in increments of $2.00.

It was assumed that corn irrigated by a LESA center pivot requires 20 acre-inches of water annually. For the other five irrigation systems, the amount of water pumped was adjusted by comparing the relative application efficiency of each system to that of the LESA center pivot (Table 8).

When the price of natural gas price increases from $4.00 to $14.00 per MCF, the total irrigation cost per acre-inch for each system more than doubles (Table 8). As natural gas prices rise, so do the savings on pumping costs for the irrigation systems that have higher application efficiencies.

For example, at $4.00 per MCF, a producer would save $43.22 per acre (a decrease from $117.33 to $74.11 per acre) by using LEPA center pivot instead of furrow. At $14.00 per MCF, the savings would increase to $151.30 (from $259.37 to $410.67) per acre.

This is the result of fuel costs increasing by $293.34 (from $117.33 to $410.67) per acre for furrow, while LEPA increases by

**Table 7. Comparison of net investment cost and benefits of irrigation technology adoption at three water-use scenarios**

| | ---------- $/ac ---------- | | | | |
|---|---|---|---|---|---|
| | | | ---------- Net benefits ---------- | | |
| System | Net investment cost | Change in net investment[1] | High water use | Intermediate water use | Low water use |
| Furrow | 183.62 | — | — | — | — |
| MESA | 467.57 | 283.95 | 999.17 | 817.60 | 631.70 |
| LESA | 467.57 | 283.95 | 1,531.75 | 1,206.25 | 869.44 |
| LEPA | 467.57 | 283.95 | 1,747.71 | 1,359.04 | 966.22 |
| SDI | 1,009.13 | 825.51 | 1,274.21 | 873.88 | 465.17 |

[1] Change in net investment cost from furrow

**Table 8. Annual estimated fuel costs for effective irrigation water applied to 1 acre of irrigated corn at alternative gas prices for five irrigation systems at a 350-foot lift**

| Gas price ($/MCF) | | 4 | 6 | 8 | 10 | 12 | 14 |
|---|---|---|---|---|---|---|---|
| Irrigation system | Water applied (in./ac) | Fuel costs ($/ac) | | | | | |
| Furrow | 29.33 | 117.33 | 176.00 | 234.67 | 293.33 | 352.00 | 410.67 |
| MESA | 22.56 | 90.26 | 135.38 | 180.51 | 225.64 | 270.77 | 315.90 |
| LESA | 20.00 | 80.00 | 120.00 | 160.00 | 200.00 | 240.00 | 280.00 |
| LEPA | 18.53 | 74.11 | 111.16 | 148.21 | 185.26 | 222.32 | 259.37 |
| SDI | 18.14 | 72.58 | 108.87 | 145.15 | 181.44 | 217.73 | 254.02 |

only $185.26 (from $74.11 to $259.37) per acre. The more efficient the system, the more insulated a producer is from fuel price changes.

## Effect of lift on pumping cost

Fuel costs are affected by the depth from which the irrigation water must be pumped (pumping lift). In this study, the fuel costs for irrigating corn were estimated for the different irrigation systems at pumping lifts ranging from 150 feet to 550 feet in 100-foot increments to determine the impact of pumping lift (Table 9). The relative efficiency of each system was factored into these calculations.

**Table 9. Annual estimated fuel costs for pumping water to irrigate corn for five pumping lifts and five irrigation systems (dollars per acre)[1]**

| Pumping lift | | 150 ft | 250 ft | 350 ft | 450 ft | 550 ft |
|---|---|---|---|---|---|---|
| Irrigation system | Water applied (in./ac) | $/ac | | | | |
| Furrow | 29.33 | 130.83 | 182.75 | 224.99 | 242.88 | 268.40 |
| MESA | 22.56 | 120.94 | 158.40 | 187.51 | 203.75 | 219.32 |
| LESA | 20.00 | 95.40 | 129.80 | 157.80 | 169.60 | 187.00 |
| LEPA | 18.53 | 88.37 | 120.24 | 146.17 | 157.10 | 173.22 |
| SDI | 18.14 | 86.55 | 117.76 | 143.16 | 153.86 | 169.65 |

[1] Natural gas price of $6.00 per MCF was assumed.

The study found that the less efficient the irrigation system, the greater the effect of the price of fuel and pumping lift on the cost to produce an irrigated crop.

The fuel cost for a LEPA center pivot at a 250-foot pumping lift was $120.24; at 550 feet, the cost was $173.22, an increase of $52.98 per acre of irrigated corn. For that system, fuel cost increased by 44 percent as pumping lift increased from 250 feet to 550 feet.

For furrow, the pumping cost was $182.75 at 250 feet and $268.40 at 550 feet. This was an increase of $85.65 per acre, which was $32.67 more than LEPA center pivot. The fuel costs for each irrigated acre of corn were $224.99 and $146.17 at a 350-foot pumping lift using furrow and LEPA center pivot, respectively.

At 350-foot pumping lift, producers will be able to save about $78.82 in fuel costs for each irrigated acre by changing to more-efficient irrigation systems and improved technologies.

The savings in fuel cost by shifting from furrow to LEPA increases to $95.18 for every irrigated acre of corn at the 550-foot pumping lift. This finding indicates that the farther water must be pumped from the ground, the more savings that growers will realize by adopting a more efficient irrigation system.

## Correlation between amount of water pumped and fixed pumping costs

To analyze the effect of the amount of water pumped on fixed cost per acre-inch, researchers calculated the fixed costs for all irrigation systems at a 350-foot pumping lift. The amounts of water analyzed ranged from 10 to 30 acre-inches per acre.

It is obvious that fixed cost per acre-inch has an inverse relationship to the amount of water pumped (Fig. 8). That is, the less water pumped, the higher the fixed cost per acre-inch.

At 10 acre-inches of water, the fixed cost per acre-inch of water pumped using subsurface drip was $7.69; for furrow, the fixed cost was $2.23. However, as the amount of water pumped increased to 30 acre-inches, the fixed cost dropped to $2.56 for subsurface drip and to $0.74 for furrow. Therefore, the difference in fixed cost of the systems narrowed significantly, from $5.46 per acre-inch (from $7.69 to $2.23) to $1.82 per acre-inch ($2.56 to $0.74) as use increased from 10 to 30 acre-inches per year.

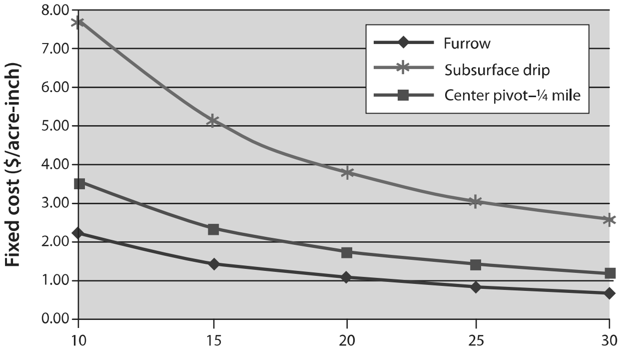

**Figure 8. Changes in fixed cost as affected by the amount of water pumped in three types of irrigation systems.**

For center pivots, the fixed cost per acre-inch ranged from $3.58 to $1.19 for 10 acre-inches to 30 acre-inches applied, respectively.

It may be deduced that producers tend to pump more water to reduce fixed cost per acre-inch. The large investments involved in adopting more efficient irrigation technology also encourage investors to increase water pumping to recover their investments as soon as possible.

## Effect of wage rate on pumping costs

The availability and cost of labor greatly affect the selection of an irrigation system. To evaluate labor charges accurately, growers must identify all costs. For example, be sure to factor in the costs of transportation, meals, lodging, insurance, and/or taxes if you provide or pay them. If you do not identify all labor costs, your estimate of the value of a particular irrigation system may be inaccurate.

The labor costs for irrigated corn were calculated at five wage rates for the five irrigation systems (Table 10). Labor costs at $12 per hour using furrow and LEPA center pivot were $28.35 and $11.29 per acre, respectively. By switching to more an efficient irrigation system, growers can reduce labor costs by $17.06 for each acre irrigated annually.

**Table 10. Labor costs for irrigated corn at five wage rates for five irrigation systems**

| Wage rate ($/hr) | | 10 | 12 | 14 | 16 | 18 |
|---|---|---|---|---|---|---|
| Irrigation system | Water applied acre-inches | ------------Labor cost $/ac------------ | | | | |
| Furrow | 29.33 | 23.63 | 28.35 | 33.08 | 37.80 | 42.53 |
| MESA | 22.56 | 13.90 | 16.68 | 19.46 | 22.24 | 25.02 |
| LESA | 20.00 | 10.88 | 13.05 | 15.23 | 17.40 | 19.58 |
| LEPA | 18.53 | 9.41 | 11.29 | 13.18 | 15.06 | 16.94 |
| SDI | 18.14 | 9.01 | 10.82 | 12.62 | 14.42 | 16.22 |

The savings in labor cost by shifting from furrow to LEPA center pivot increase to $22.74 for every irrigated acre of corn at the labor wage rate of $16 per hour. The comparison indicates that as wage rates rise, it becomes more cost effective to adopt a more efficient irrigation system.

## Effects of efficiency in natural gas engines

Natural gas is a preferred irrigation fuel where it is available because it typically costs the least per unit of energy, usually by a significant amount. However, natural gas power plants are not always the most cost-effective means for pumping irrigation water because of the relatively low thermal efficiency of spark ignition, internal combustion engines. This is especially true if engine efficiency has declined after multiple years of service.

The standard expected efficiency for a new natural gas engine in a pumping plant setting is about 25 percent, meaning that about one quarter of the fuel that is consumed by the engine will be converted to usable power. When combined with standard efficiencies of the pump (~75 percent) and right-angle gearhead (95 percent), the standard overall efficiency of a natural gas pumping plant is about 16 percent. Field studies conducted throughout the Texas High Plains over the past 30 years have indicated that many pumping plants operate with engine efficiencies as low as 15 percent and overall efficiencies as low as 10 percent.

At a natural gas pumping plant, the engine is typically the least efficient component and is, therefore, the component most sensitive to replacement based on efficiency. Tables 11 and 12 list the first-year energy-cost savings for multiple natural gas prices for 75- and 125-horsepower pumping plants.

Seasonal energy savings are found by subtracting the seasonal energy savings of an existing natural gas engine from those of a more efficient, newer natural gas engine. For example, at a 75-horsepower pumping plant with $8.00 per MCF natural gas, replacing an 18-percent-efficient engine with a 24-percent-efficient engine would produce a direct annual energy cost savings of $4,200 ($7,600 – $3,400).

Seasonal energy savings are expected to occur over the life of the engine; however, the benefits in future years must be discounted to account for the time value of money. Total discounted energy savings prices for 75- and 125-horsepower pumping plants at various natural gas prices are estimated assuming an engine life of 5 years and a discount rate of 6 percent (Tables 11 and 12). These values can be used to identify the amount a producer can pay to upgrade engine efficiency.

Again, looking at the same 75-horsepower pumping plant with $8.00 per MCF natural gas, replacing an 18-percent-efficient engine with a 24-percent-efficient engine would produce a discounted energy cost savings of $19,000 ($34,100 – $15,100) over a 5-year period. This analysis suggests that a producer would be better off financially by choosing the higher efficiency engine if it could be bought for less than $19,000 more, given the useful life and natural gas price assumptions.

This approach makes a compelling argument for replacing inefficient engines with more efficient models, especially considering that engine efficiency decreases with time.

Because of the inefficiency of internal combustion engines and the cost structure of natural gas, researchers have been working to develop highly efficient natural gas engines. Prototype engines have shown over 40 percent thermal efficiency in controlled environments and up to 30 percent thermal efficiency in field tests, up to 125 horsepower.

Much of the work on improved efficiencies has also helped with emissions compliance, because reduced fuel consumption is an effective way to reduce emissions. The

**Table 11. Seasonal and total discounted energy cost reduction from replacing a natural gas engine, based on 75-horsepower pumping requirements: 400 gallons per minute, 300-foot lift, and 20 pounds per square inch (2,000 hours or about 1,775 acre-inches)[1]**

| | ---------- Seasonal energy cost reduction ---------- | | | ------- Total discounted energy cost reduction ------- | | |
|---|---|---|---|---|---|---|
| | ------------------------------------------------ Natural gas price ($/MCF) ------------------------------------------------ | | | | | |
| Engine efficiency (%) | 4 | 8 | 12 | 4 | 8 | 12 |
| 15 | — | — | — | — | — | — |
| 16 | $ 600 | $ 1,300 | $ 1,900 | $ 2,800 | $ 5,700 | $ 8,500 |
| 18 | $ 1,700 | $ 3,400 | $ 5,100 | $ 7,600 | $ 15,100 | $ 22,700 |
| 20 | $ 2,500 | $ 5,100 | $ 7,600 | $ 11,400 | $ 22,700 | $ 34,100 |
| 22 | $ 3,200 | $ 6,500 | $ 9,700 | $ 14,500 | $ 28,900 | $ 43,400 |
| 24 | $ 3,800 | $ 7,600 | $ 11,500 | $ 17,000 | $ 34,100 | $ 51,100 |
| 26 | $ 4,300 | $ 8,600 | $ 12,900 | $ 19,200 | $ 38,500 | $ 57,700 |
| 28 | $ 4,700 | $ 9,500 | $ 14,200 | $ 21,100 | $ 42,200 | $ 63,300 |
| 30 | $ 5,100 | $ 10,200 | $ 15,300 | $ 22,700 | $ 45,400 | $ 68,200 |

[1] 6% discount rate, 5 years

**Table 12. Seasonal and total discounted energy cost reduction from replacing a natural gas engine, based on 125-horsepower pumping requirements: 750 gallons per minute, 400-foot lift, and 20 pounds per square inch (2,000 hours, or about 3,300 acre-inches)[1]**

| | ---------- Seasonal energy cost reduction ---------- | | | ------- Total discounted energy cost reduction ------- | | |
|---|---|---|---|---|---|---|
| | ------------------------------------------------ Natural gas price ($/MCF) ------------------------------------------------ | | | | | |
| Engine efficiency (%) | 4 | 8 | 12 | 4 | 8 | 12 |
| 15 | — | — | — | — | — | — |
| 16 | $ 1,100 | $ 2,100 | $ 3,200 | $ 4,700 | $ 9,500 | $ 14,200 |
| 18 | $ 2,800 | $ 5,700 | $ 8,500 | $ 12,600 | $ 25,200 | $ 37,900 |
| 20 | $ 4,200 | $ 8,500 | $ 12,700 | $ 18,900 | $ 37,900 | $ 56,800 |
| 22 | $ 5,400 | $ 10,800 | $ 16,200 | $ 24,100 | $ 48,200 | $ 72,300 |
| 24 | $ 6,400 | $ 12,700 | $ 19,100 | $ 28,400 | $ 56,800 | $ 85,200 |
| 26 | $ 7,200 | $ 14,400 | $ 21,500 | $ 32,000 | $ 64,100 | $ 96,100 |
| 28 | $ 7,900 | $ 15,800 | $ 23,600 | $ 35,200 | $ 70,300 | $ 105,500 |
| 30 | $ 8,500 | $ 17,000 | $ 25,400 | $ 37,900 | $ 75,700 | $ 113,600 |

[1] 6% discount rate, 5 years

current method for meeting emissions compliance is to retrofit existing engine platforms with catalytic convertors and oxygen sensors. Although catalytic convertors do reduce point source emissions, they also reduce engine efficiency and increase maintenance costs.

At the time of publication, no highly efficient, non-catalyst natural gas irrigation engine is production ready.

## Conversion to an electric-powered irrigation system

Volatile natural gas prices have caused many producers to convert or consider converting their irrigation systems to use alternative energy sources. Most irrigation systems in Texas are powered by either natural gas or electricity. To make an informed decision before any actual conversion, producers should compare the costs of their existing natural gas powered system to the cost of converting and operating an electric-powered system.

Following is a comparison between irrigation systems powered by natural gas and those powered by electricity. The costs associated each system were evaluated over a 20-year period using two pumping lifts (200 and 500 feet), three crops (high, intermediate, and low water use), natural gas prices ranging from $2.00 per MCF to $16.00 per MCF, and a flow capacity of 600 gallons per minute for a quarter-mile center pivot.

Table 13 shows the expenses related to investment and maintenance of a natural gas engine and electric motor. It was assumed that producers had a natural gas powered irrigation system in place. The investment costs for natural gas engines of about $11,000 at 200 feet and $36,000 at 500 feet were used as the replacement costs of the engine over the 20-year period. Investment costs for the electric motor were about $4,800 at 200 feet and $8,800 at 500 feet. Also, the cost to convert from a natural gas system to electric ranged from about $7,500 at 200 feet to $15,400 at 500 feet and included the fuse, control panel, pump conversion, and labor and installation.

The total costs associated with each system over the 20-year period were estimated on a per-acre basis in 2011 dollars and included conversion expenses, irrigation fuel, repairs, and any necessary replacement costs to the

**Table 13. Fixed and variable costs for a natural gas irrigation engine and an electric motor**

| | --------------Engine/motor costs-------------- | | | Useful life | Salvage value | ---------------LMR[1]--------------- | |
|---|---|---|---|---|---|---|---|
| Lift (ft) | Investment ($) | Conversion ($) | $/ac-yr | Years | % of Investment | Annual ($) | $/ac-yr |
| **Natural gas irrigation engine** | | | | | | | |
| 200 | 10,997 | — | 7.64 | 12 | 10% | 1,084 | 9.03 |
| 500 | 35,940 | — | 24.96 | 12 | 10% | 1,480 | 12.33 |
| **Electric motor** | | | | | | | |
| 200 | 4,812 | 7,530 | 6.86 | 15 | 10% | 420 | 3.50 |
| 500 | 8,835 | 15,440 | 13.49 | 15 | 10% | 722 | 6.02 |

[1] LMR=Lubrication, maintenance, and repairs

systems. Each cost stream was evaluated for the different levels of natural gas prices and pumping lifts.

Conversion to an electric-powered system becomes feasible at the price where the cost lines cross. For example, the cost lines for each system (C1 and C2) for an intermediate water use crop at a pumping lift of 200 feet are presented in Figure 9. C1 represents the cost of natural gas powered irrigation, which is assumed to be the system currently in use, and C2 represents the cost for converting to electric and associated costs for operating that system over a 20-year time horizon. The two cost lines intersect at $4.00 per MCF or $0.07 per kWh, indicating that conversion from natural gas to electric is plausible at this point.

The breakeven prices for all pumping lifts and crops are given in Table 14. The type of crop grown does not significantly affect breakeven prices. Overall, it is beneficial to convert lower pumping lifts first at natural gas prices above $3.84 per MCF and higher pumping lifts at natural gas prices above $4.38 per MCF (or about $0.07 per kWh under both pumping lifts).

**Table 14. Breakeven prices for converting an irrigation system from natural-gas powered to electric powered**

| Lift (ft) | Water use | BE price ($/Mcf) | BE price ($/kWh) |
|---|---|---|---|
| 200 | High | 4.10 | 0.0704 |
| | Intermediate | 4.02 | 0.0701 |
| | Low | 3.84 | 0.0694 |
| 500 | High | 4.94 | 0.0736 |
| | Intermediate | 4.78 | 0.0730 |
| | Low | 4.38 | 0.0715 |

Before making a decision, producers should consider other factors:

- Proximity to a three-phase electric line
- Line extension costs
- Peak factor charges
- Conversion incentives
- Cost of repairs and labor
- Price stability

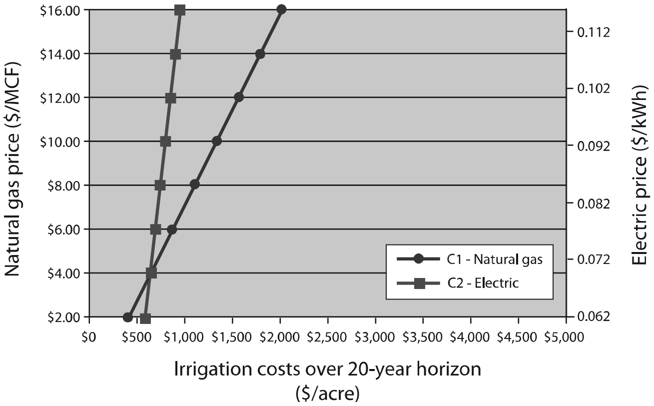

**Figure 9. Natural gas and electric irrigation costs for an intermediate water use crop at a 200-foot lift.**

Possibly the most important consideration is the proximity to a three-phase electric line. Line extensions were not included in the comparison, and the cost can be high if the well is far from power lines. The electric company may also assess initial connection fees or peak factor charges.

On the other hand, some electric companies may offer incentives to irrigated agricultural producers to encourage conversion and offset some of the expense. In addition, electric systems tend to have a longer life with fewer repair and labor expenses. Finally, electric prices fluctuate somewhat with natural gas prices, but they tend to be more stable overall than natural gas prices, which would be an advantage for producers.

## Study limitations

Researchers evaluated the predominant irrigation systems in Texas and analyzed the major factors that affect their economic feasibility. The discussion of some items was omitted or limited because of study and space limitations.

One limitation in the analysis was that yields were held constant even when the amount of water applied by the distribution system was modified by its application efficiency. Although this approach is sound, it does not account for potential yield gains from more frequent irrigations that can result through center pivots and especially SDI as compared to furrow.

## Summary

Investing in a new irrigation system is expensive and complex, with many factors needing to be evaluated, including water availability, pumping lift, labor cost, fuel cost, tax rate, soil type, and field topography.

Overlaying these factors are the differences in the costs and water application efficiencies of the various irrigation systems. These factors make it difficult to make a wise investment decision.

To help farmers weigh these factors and make these decisions, researchers studied the costs and associated benefits of five commonly used irrigation systems in Texas: furrow, mid-elevation spray application center pivot, low elevation spray application center pivot, low energy precision application center pivot, and subsurface drip.

The study found that:

- Furrow irrigation systems require less capital investment but have lower water application efficiency and are more labor intensive than the other irrigation systems.
- Compared to furrow irrigation, center pivot systems offer more than enough benefits in application efficiency and reduction in field operations to offset the additional costs.
- Where it is feasible to use, half-mile center pivot offers substantial savings compared to quarter-mile length systems.
- Among the three center pivot alternatives, LEPA center pivot systems generate the highest benefits at low, intermediate, and high water-requirement scenarios.
- Advanced irrigation technologies are best suited to crops with high water needs, particularly in areas with deep pumping lifts. Producers using advanced systems will have not only lower pumping costs, but also potential savings from the need for fewer field operations.
- Compared to LEPA center pivot systems, subsurface drip irrigation (SDI) is not economically feasible for any crop water-use scenario because of its relatively high investment and small gain in application efficiency. For most crops, adoption of SDI may be limited to land where pivots cannot physically be installed.
- However, producers should closely evaluate using SDI systems for high-value crops. Research suggests that SDI systems may improve the application efficiency and the timing of frequent applications. These improvements may increase acreage and yields enough to justify the additional investment costs of subsurface drip systems.

Researchers also studied the effect on pumping cost of variations in fuel prices, pumping lift, amount of water pumped, and labor wage rate. Results indicated that:

- The less efficient the irrigation system, the more effect that fuel price, pumping lift, and wage rate have on the cost of producing an irrigated crop. Therefore, when there is inflation or volatility of these cost factors, it is more feasible to adopt more efficient irrigation systems and technology.
- As more water is pumped, the fixed cost per acre-inch drops. Therefore, pumping more water encourages farmers to recapture their irrigation system investment more quickly.
- It is beneficial to replace inefficient engines with more efficient models.
- Conversion from natural-gas-powered irrigation to electric-powered irrigation is economically feasible for lower pumping lifts at natural gas prices above \$3.84 per MCF and higher pumping lifts at natural gas prices above \$4.38 per MCF (or about \$0.07 per kWh under both pumping lifts).

## For more information

B-1241, *Crop and Livestock Enterprise Budgets, Texas High Plains, Projected for 2011,* Texas AgriLife Extension Service. *http://agecoext.tamu.edu/budgets/.* College Station, TX.

B-6096, *Center Pivot Irrigation,* Texas AgriLife Extension Service. College Station, TX.

Bordovsky, James P., William M. Lyle and Eduardo Segarra. 2000. "Economic Evaluation of Texas High Plains Cotton Irrigated by LEPA and Subsurface Drip." *Texas Journal of Agriculture and Natural Resources*. pp. 76–73.

Guerrero, B., S. Amosson, T. Marek, and J. Johnson. 2010. "Economic Evaluation of Wind Energy as an Alternative to Natural Gas Powered Irrigation." *Journal of Agricultural and Applied Economics,* 42.2(May 2010):277–287.

Department of Agricultural Economics, Texas AgriLife Extension. 2011. *2011 Texas Agricultural Custom Rates.* Texas AgriLife Extension Service, College Station, TX. *http://agecoext.tamu.edu.*

# Appendix

**Table A1. Estimated gross investment costs (in dollars) for alternative irrigation systems at five pumping lifts in Texas**

| Irrigation system/lift (ft) | Well | Pump | Engine | Distribution system | Total |
|---|---|---|---|---|---|
| Furrow | | | | | |
| 150 | 27,500 | 26,500 | 6,000 | 33,370 | 96,800 |
| 250 | 36,500 | 36,000 | 6,500 | 33,370 | 115,800 |
| 350 | 45,500 | 46,000 | 9,000 | 33,370 | 137,300 |
| 450 | 54,500 | 56,000 | 9,000 | 33,370 | 156,300 |
| 550 | 64,000 | 66,500 | 35,000 | 33,370 | 202,300 |
| MESA | | | | | |
| 150 | 27,500 | 26,500 | 6,000 | 69,500 | 129,500 |
| 250 | 36,500 | 36,000 | 6,500 | 69,500 | 148,500 |
| 350 | 45,500 | 46,000 | 9,000 | 69,500 | 170,000 |
| 450 | 54,500 | 56,000 | 9,000 | 69,500 | 189,000 |
| 550 | 64,000 | 66,500 | 35,000 | 69,500 | 235,000 |
| LESA | | | | | |
| 150 | 27,500 | 26,500 | 6,000 | 69,500 | 129,500 |
| 250 | 36,500 | 36,000 | 6,500 | 69,500 | 148,500 |
| 350 | 45,500 | 46,000 | 9,000 | 69,500 | 170,000 |
| 450 | 54,500 | 56,000 | 9,000 | 69,500 | 189,000 |
| 550 | 64,000 | 66,500 | 35,000 | 69,500 | 235,000 |
| LEPA | | | | | |
| 150 | 27,500 | 26,500 | 6,000 | 69,500 | 129,500 |
| 250 | 36,500 | 36,000 | 6,500 | 69,500 | 148,500 |
| 350 | 45,500 | 46,000 | 9,000 | 69,500 | 170,000 |
| 450 | 54,500 | 56,000 | 9,000 | 69,500 | 189,000 |
| 550 | 64,000 | 66,500 | 35,000 | 69,500 | 235,000 |
| SDI | | | | | |
| 150 | 27,500 | 26,500 | 6,000 | 192,000 | 252,000 |
| 250 | 36,500 | 36,000 | 6,500 | 192,000 | 271,000 |
| 350 | 45,500 | 46,000 | 9,000 | 192,000 | 292,500 |
| 450 | 54,500 | 56,000 | 9,000 | 192,000 | 311,500 |
| 550 | 64,000 | 66,500 | 35,000 | 192,000 | 357,500 |

**Table A2. Useful life and salvage value assumptions used to calculate depreciation of five irrigation systems**

| Item/component | Useful life (yr) | Salvage value (%) |
|---|---|---|
| Furrow | 25 | 0 |
| Center pivot | 25 | 20 |
| Subsurface drip | 25 | 20 |

**Table A3. Fixed cost for irrigating at three levels of water use under five irrigation systems**

| System/ | ------------------------ $/ac-in. ------------------------ | | | | |
|---|---|---|---|---|---|
| water use | Depreciation | Taxes | Insurance | Interest | Total |
| Furrow | | | | | |
| High | 0.28 | 0.01 | 0.04 | 0.43 | 0.76 |
| Intermediate | 0.41 | 0.02 | 0.06 | 0.61 | 1.10 |
| Low | 0.71 | 0.04 | 0.11 | 1.07 | 1.93 |
| MESA | | | | | |
| High | 0.79 | 0.05 | 0.15 | 0.59 | 1.58 |
| Intermediate | 1.13 | 0.07 | 0.21 | 0.85 | 2.26 |
| Low | 1.97 | 0.12 | 0.37 | 1.48 | 3.94 |
| LESA | | | | | |
| High | 0.89 | 0.06 | 0.17 | 0.67 | 1.79 |
| Intermediate | 1.27 | 0.08 | 0.24 | 0.95 | 2.54 |
| Low | 2.22 | 0.14 | 0.42 | 1.67 | 4.45 |
| LEPA | | | | | |
| High | 0.96 | 0.06 | 0.18 | 0.72 | 1.92 |
| Intermediate | 1.37 | 0.09 | 0.26 | 1.03 | 2.75 |
| Low | 2.40 | 0.15 | 0.45 | 1.80 | 4.80 |
| SDI | | | | | |
| High | 2.12 | 0.13 | 0.40 | 1.59 | 4.24 |
| Intermediate | 3.02 | 0.19 | 0.57 | 2.27 | 6.05 |
| Low | 5.29 | 0.33 | 0.99 | 3.97 | 10.58 |

**Table A4. Variable costs (dollars per acre-inch) for a high water-use crop (corn) for five irrigation systems at five lifts**[1]

| | --------------------- $/ac-in. --------------------- | | | |
|---|---|---|---|---|
| System/lift (ft) | Fuel | LMR | Labor | Total |
| Furrow | | | | |
| 150 | 3.52 | 2.29 | 0.83 | 6.64 |
| 250 | 4.91 | 3.19 | 0.83 | 8.94 |
| 350 | 6.04 | 3.93 | 0.83 | 10.80 |
| 450 | 6.53 | 4.24 | 0.83 | 11.60 |
| 550 | 7.22 | 4.69 | 0.83 | 12.74 |
| MESA | | | | |
| 150 | 4.23 | 2.75 | 0.63 | 7.61 |
| 250 | 5.54 | 3.60 | 0.63 | 9.77 |
| 350 | 6.55 | 4.26 | 0.63 | 11.44 |
| 450 | 7.12 | 4.63 | 0.63 | 12.38 |
| 550 | 7.66 | 4.98 | 0.63 | 13.27 |
| LESA | | | | |
| 150 | 3.76 | 2.45 | 0.56 | 6.77 |
| 250 | 5.11 | 3.32 | 0.56 | 9.00 |
| 350 | 6.22 | 4.04 | 0.56 | 10.83 |
| 450 | 6.69 | 4.35 | 0.56 | 11.59 |
| 550 | 7.37 | 4.79 | 0.56 | 12.72 |
| LEPA | | | | |
| 150 | 3.76 | 2.45 | 0.52 | 6.73 |
| 250 | 5.11 | 3.32 | 0.52 | 8.96 |
| 350 | 6.22 | 4.04 | 0.52 | 10.79 |
| 450 | 6.69 | 4.35 | 0.52 | 11.55 |
| 550 | 7.37 | 4.79 | 0.52 | 12.69 |
| SDI | | | | |
| 150 | 3.76 | 2.45 | 0.51 | 6.72 |
| 250 | 5.11 | 3.32 | 0.51 | 8.95 |
| 350 | 6.22 | 4.04 | 0.51 | 10.78 |
| 450 | 6.69 | 4.35 | 0.51 | 11.54 |
| 550 | 7.37 | 4.79 | 0.51 | 12.68 |

[1] Natural gas price of $6.00 per MCF was assumed.

**Table A5. Variable costs (dollars per acre-inch) for an intermediate water-use crop (sorghum/soybeans) for five irrigation systems at five lifts[1]**

| | ----------------------$/ac-in.---------------------- | | | |
|---|---|---|---|---|
| System/lift (ft) | Fuel | LMR | Labor | Total |
| Furrow | | | | |
| 150 | 3.52 | 2.29 | 1.19 | 6.99 |
| 250 | 4.91 | 3.19 | 1.19 | 9.29 |
| 350 | 6.04 | 3.93 | 1.19 | 11.16 |
| 450 | 6.53 | 4.24 | 1.19 | 11.96 |
| 550 | 7.22 | 4.69 | 1.19 | 13.09 |
| MESA | | | | |
| 150 | 4.23 | 2.75 | 0.91 | 7.88 |
| 250 | 5.54 | 3.60 | 0.91 | 10.04 |
| 350 | 6.55 | 4.26 | 0.91 | 11.71 |
| 450 | 7.12 | 4.63 | 0.91 | 12.66 |
| 550 | 7.66 | 4.98 | 0.91 | 13.55 |
| LESA | | | | |
| 150 | 3.76 | 2.45 | 0.80 | 7.01 |
| 250 | 5.11 | 3.32 | 0.80 | 9.24 |
| 350 | 6.22 | 4.04 | 0.80 | 11.07 |
| 450 | 6.69 | 4.35 | 0.80 | 11.83 |
| 550 | 7.37 | 4.79 | 0.80 | 12.96 |
| LEPA | | | | |
| 150 | 3.76 | 2.45 | 0.75 | 6.96 |
| 250 | 5.11 | 3.32 | 0.75 | 9.19 |
| 350 | 6.22 | 4.04 | 0.75 | 11.01 |
| 450 | 6.69 | 4.35 | 0.75 | 11.78 |
| 550 | 7.37 | 4.79 | 0.75 | 12.91 |
| SDI | | | | |
| 150 | 3.76 | 2.45 | 0.73 | 6.94 |
| 250 | 5.11 | 3.32 | 0.73 | 9.17 |
| 350 | 6.22 | 4.04 | 0.73 | 11.00 |
| 450 | 6.69 | 4.35 | 0.73 | 11.76 |
| 550 | 7.37 | 4.79 | 0.73 | 12.90 |

[1] Natural gas price of $6.00 per MCF was assumed

**Table A6. Variable costs (dollars per acre-inch) for a low water use crop (cotton) for five irrigation systems at five lifts[1]**

| | ---------------------- $/ac-in. ---------------------- | | | |
|---|---|---|---|---|
| System/lift (ft) | Fuel | LMR | Labor | Total |
| Furrow | | | | |
| 150 | 3.52 | 2.29 | 2.07 | 7.88 |
| 250 | 4.91 | 3.19 | 2.07 | 10.18 |
| 350 | 6.04 | 3.93 | 2.07 | 12.05 |
| 450 | 6.53 | 4.24 | 2.07 | 12.85 |
| 550 | 7.22 | 4.69 | 2.07 | 13.98 |
| MESA | | | | |
| 150 | 4.23 | 2.75 | 1.59 | 8.56 |
| 250 | 5.54 | 3.60 | 1.59 | 10.72 |
| 350 | 6.55 | 4.26 | 1.59 | 12.39 |
| 450 | 7.12 | 4.63 | 1.59 | 13.33 |
| 550 | 7.66 | 4.98 | 1.59 | 14.22 |
| LESA | | | | |
| 150 | 3.76 | 2.45 | 1.40 | 7.61 |
| 250 | 5.11 | 3.32 | 1.40 | 9.84 |
| 350 | 6.22 | 4.04 | 1.40 | 11.67 |
| 450 | 6.69 | 4.35 | 1.40 | 12.43 |
| 550 | 7.37 | 4.79 | 1.40 | 13.56 |
| LEPA | | | | |
| 150 | 3.76 | 2.45 | 1.31 | 7.52 |
| 250 | 5.11 | 3.32 | 1.31 | 9.75 |
| 350 | 6.22 | 4.04 | 1.31 | 11.57 |
| 450 | 6.69 | 4.35 | 1.31 | 12.34 |
| 550 | 7.37 | 4.79 | 1.31 | 13.47 |
| SDI | | | | |
| 150 | 3.76 | 2.45 | 1.28 | 7.49 |
| 250 | 5.11 | 3.32 | 1.28 | 9.72 |
| 350 | 6.22 | 4.04 | 1.28 | 11.54 |
| 450 | 6.69 | 4.35 | 1.28 | 12.31 |
| 550 | 7.37 | 4.79 | 1.28 | 13.44 |

[1] Natural gas price of $6.00 per MCF was assumed.

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