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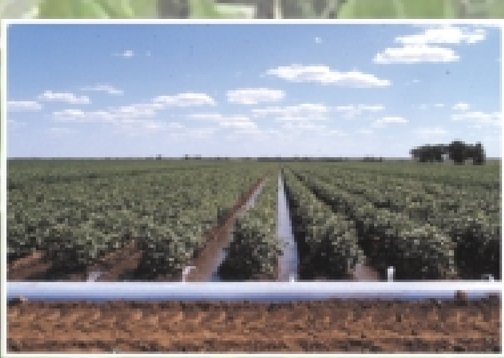
$ Economics of Irrigation Systems

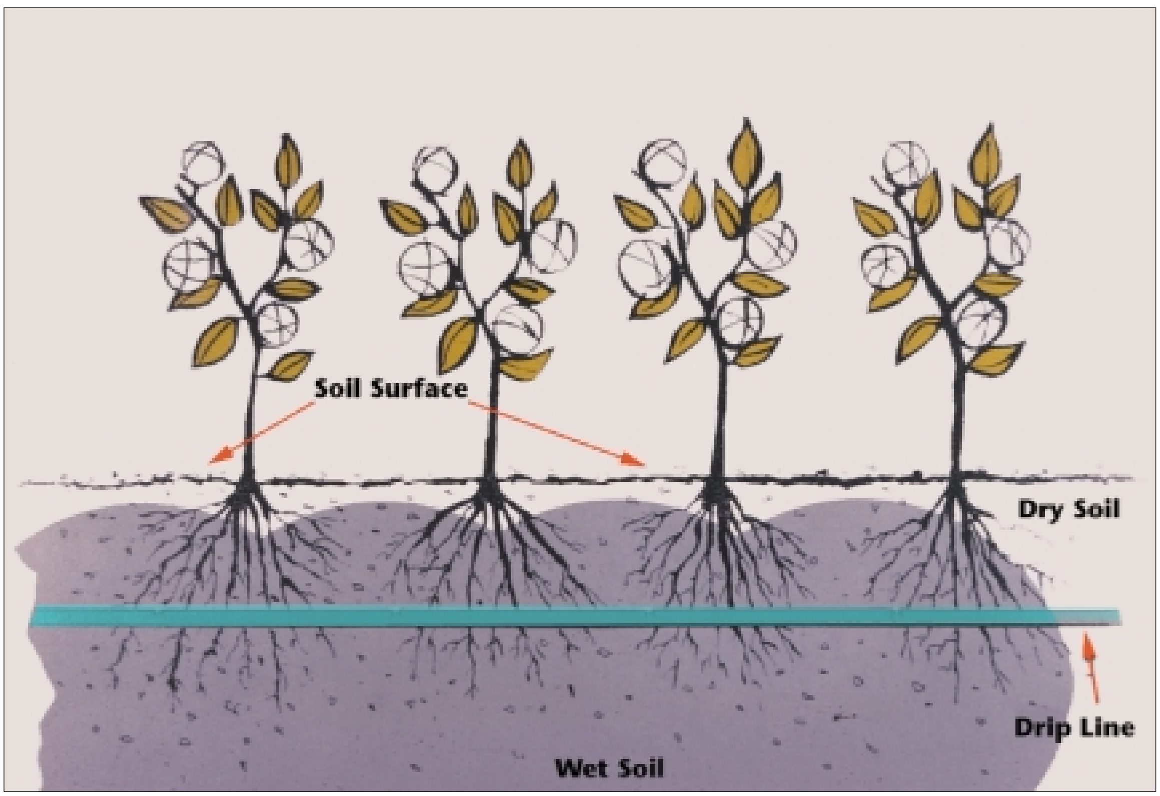


Front cover insets: (top, from left) conventional furrow irrigation on corn; surge flow valve, solar powered; (middle) low energy precision application (LEPA) center pivot; (bottom, from left) conventional furrow, polypipe, on cotton; and low elevation spray application (LESA) on peanuts. Background photo: mid-elevation spray application (MESA) center pivot, single head.

Opposite page: Subsurface drip irrigation system diagram.

Back cover inset: Low energy precision application (LEPA) center pivot on peanut.

Economics of Irrigation Systems



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Economics of Irrigation Systems

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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: the availability of water; the system's application efficiency; the depth from which the water must be pumped, or pumping lifts; the operating pressure of the design; financing; savings in field operations; energy sources; energy prices; crop mix; economies of scale; labor availability; and commodity prices.

To help producers make decisions about irrigation systems, Texas A&M University System researchers studied the costs and benefits of six types of irrigation systems commonly used in Texas: conventional furrow irrigation (CF); surge flow furrow (SF); 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 of center pivots.
- The potential use of chemigation.
- The impact of other major factors such as fuel prices, pumping lift and labor costs.

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, farmers should compare their operations 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). The terrain and soil type were assumed not to 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:

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

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

The calculations were made using the LESA center pivot 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 conventional 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 take into consideration 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 six systems studied:

- Furrow and surge flow systems usually had operating pressures of about 10 pounds per square inch (psi).
- LESA, LEPA and SDI usually had an intermediate operating pressure of 15 psi, depending on the flow rate.
- MESA center pivot systems required higher pressure, about 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 that system's design. As GPM declines, growers must close furrow gates, renozzle center pivots and reduce the number of emitter lines to make each system work properly.

Irrigation Systems

The six irrigation systems studied had varying designs, costs, management requirements, advantages and disadvan-

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Table 1. Basic assumptions for six irrigation distribution systems.

Irrigation System	Operating Pressure (psi)*	Application Efficiency (%)	Efficiency Index	Acres Irrigated
Conventional furrow (CF)	10	60	1.47	160
Surge flow furrow (SF)	10	75	1.17	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

*PSI = Pounds of pressure per square inch of water.

tages. Producers should evaluate these systems in light of the characteristics and requirements specific to their farming/ranching operations.

Conventional furrow irrigation (CF)

Conventional furrow irrigation delivers water from an irrigation well via an underground supply pipeline, to which gated pipe is connected. The water flows by gravity on the surface through the furrows between crop rows (Figure 1).

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 this study, two irrigation sets of gated pipe were used to allow the water flow to be changed without interruption.

Figure 1. Conventional furrow irrigation on cotton.

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. Furrow gates are installed to deliver water between crop rows, the same as gated pipe (Figure 2). The limitation of polypipe is that it is much less durable and is usually replaced every 1 to 2 years.

With good planning, land preparation and management, CF irrigation can achieve 60 percent water application efficiency (Table 1). That is, 60 percent of the water irrigated is used by the crop. CF 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, installing surge flow valves, adjusting gates and modifying the shape, spacing or length of the furrow.

CF irrigation usually requires additional tillage preparation and labor, especially if the terrain varies in elevation. Other disadvantages of furrow irrigation include:

Figure 2. Conventional furrow polypipe on cotton.

- 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, consequently, lowering overall crop yield.

Furrow irrigation usually applies water at higher increments than do center pivot or subsurface drip systems.

- The risk of nitrate leaching increases.

To address these problems, farmers can take remedial measures such as laser leveling, filter strips, mechanical straw mulching, surge flow, reduced tillage, furrow design, and sediment ponds with tailwater pump back features.

Surge flow furrow (SF)

Surge flow irrigation was developed to address some of the problems associated with furrow irrigation. The primary difference between conventional furrow and surge flow is the installation and function of a surge valve (Figure 3), which intermittently applies water to two areas of the field.

Figure 3. Surge flow furrow on wheat.

A surge valve can improve application efficiency by about 15 percent (Table 1). Research has shown that surge flow can reduce runoff and improve distribution efficiency. It applies water more uniformly and therefore reduces the deep percolation losses associated with furrow irrigation.

Another advantage of SF irrigation, unrelated to the improvements in irrigation system performance, is that a surge valve can improve irrigation system management without a large increase in labor or capital.

There are no detailed, accurate guidelines for setting surge time (number of hours of irrigation) on a particular site. Surge time and the level of irrigation efficiency achieved are influenced by the site's soil type, field terrain and tillage preparation.

Three potential disadvantages are associated with surge flow:

- It may not always reduce the amount of time it takes water to move down the furrow.
- Net water application may be lowered because of the programmed surge time. Too little water may filter into the soil during an application to be adequate for the growing crop until the next allocation.
- It requires more management, including monitoring how long it takes water to advance down the field on each surge, in order to reduce potential water loss.

Farmers must monitor soil moisture more closely and schedule irrigation properly to make sure that enough—but not too much—water is applied.

Nonetheless, surge flow is an improved furrow irrigation system.

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 level.

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 (Figure 4).

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

The nozzle pressure for MESA varies, depending on 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. The operating pressure can be lowered to 6 psi or less if the sprayer heads are positioned 60 to 80 inches apart.

Mid-elevation spray application 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 the foliage. Field comparisons show a total water loss (air, foliage and soil) of 20 to 25 percent from MESA center pivot irrigation systems where applicators are set above the crop canopy.

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

Low elevation spray application (LESA) center pivot

With 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. Each applicator is attached to a flexible drop hose, which is connected to a gooseneck or furrow arm on the mainline.

Weights, positioned immediately upstream from the pressure regulator and/or the applicator, 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 is no wider than 80 inches. If they are installed and managed properly, LESA drops can be spaced on conventional 8- to 10-foot MESA spacing successfully.

Corn should be planted in circle rows and water sprayed underneath 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 water to spray horizontally.

Grain sorghum and soybeans can also be planted in straight rows. In wheat, the foliage may cause the water distribution to

Figure 4. MESA center pivot, half-mile system.

be significantly uneven. To improve the water distribution, you 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 wet less foliage, especially when the crop is planted in a circle. This lowers the amount of water lost to evaporation (Figure 5). The water application efficiency for LESA usually averages 85 to 90 percent (Table 1), but may be less in open, lower profile crops such as cotton, peanuts or broadcast crops such as wheat or alfalfa.

Figure 5. LESA center pivot on cotton.

When 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 to attach 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 with either a bubble applicator 12 to 18 inches above ground level or drag socks or hoses that release water on the ground.

Figure 6. LEPA center pivot with drag sock.

Drag socks help reduce furrow erosion; double-ended socks are designed to protect and maintain furrow dikes (Figure 6). When needed, drag socks and hose adapters can be easily removed from the applicator and replaced with a spray or chemigation pad.

Another product, the LEPA "quad" applicator, delivers a bubble water pattern (Figure 7) that can be reset to an optional spray pattern for germination, chemigation and other in-field adjustments.

Figure 7. LEPA center pivot with bubble applicator on corn.

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 to 98 percent of the irrigation water pumped through a LEPA system (Table 1). The water application is precise and concentrated.

LEPA can be used successfully 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.

This system 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 soil type, crop 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.

The amount of water available dictates the system's design, control and management. SDI is a low-pressure, low-volume irrigation system (Figures 8a and b) like the LEPA center pivot.

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 minmize leaching of soluble chemicals.

Figures 8a and b. Subsurface drip irrigation.

The disadvantages of a subsurface drip system include:

- It requires intensive management.
- During dry springs, an SDI system may be unable to deliver enough water to germinate the crop.
- It is essential that the system 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 the factors are taken under 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, field operations, etc. These benefits may more than offset the cost of adopting the system.

Because a dollar today is not worth the same as 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 six irrigation systems studied are listed in Table 2. The costs for the well, pump and engine 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 $165.32 per acre for conventional furrow to $832.23 for subsurface drip irrigation with emitter lines spaced 5 feet apart. The gross investment for quarter-mile center pivot systems varied from $341.68 (MESA) to $376.00 (LEPA) per acre.

The total investment costs for each irrigation system, including well, pump and engine for five pumping lifts, are given in Appendix A, Table 1.

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 investment by more than 30 percent, or by $107.18 (from $341.68 to $234.56) to $126.00 (from $376.00 to $250.00) per acre (Table 2). In addition, the corners become more functional for farming increasing in size from 8 to 30 acres.

To calculate the net investment, subtract the salvage value and discounted tax savings associated with a new system from the gross investment cost. 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 LESA center pivot and conventional furrow is $115.42 per acre ($268.05-$152.63), given a 15 percent tax and 6 percent discount rates. The net investment for a subsurface drip irrigation system, $614.71 per acre, is substantially less than the gross investment of $832.23 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 $44.25 (from $614.71 to $570.46) per acre; the net investment in furrow is reduced by $10.98 (from $152.63 to $141.65) 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 ($44.25 versus $10.98 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).

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	X	# acre-inches of water required for the irrigation system	=	Annual pumping costs per acre

Table 2. Investment costs of alternative irrigation systems.

Distribution System	Gross Investment ($/acre)	Net Investment[1] ($/acre)	Net Investment[2] ($/acre)
Conventional furrow (CF)	165.32	152.63	141.65
Surge flow (SF)	185.32	171.11	158.79
Mid-elevation spray application (MESA)	341.68	252.37	234.21
Low elevation spray application (LESA)	366.90	268.05	252.18
Low energy precision application (LEPA)	376.00	277.73	257.73
Mid-elevation spray application (MESA)*	234.56	173.26	160.78
Low elevation spray application (LESA)*	245.91	181.64	168.56
Low energy precision application (LEPA)*	250.00	184.66	171.37
Subsurface drip irrigation (SDI)	832.23	614.71	570.46

*Half-mile center pivot.

[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 Appendix A, Table 2.

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	X	Application efficiency index for the irrigation system	=	Amount of water required for the irrigation system

The 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 acre-inches are pumped through the LESA center pivot system, a conventional furrow system would require 20.58 acre-inches of water (14 x 1.47) to apply the same effective amount of water to the crop at the intermediate water use level (Table 3).

Fixed operating costs

Fixed operating costs include 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 0.6 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.

Table 4 lists the fixed costs in dollars per acre-inch of water pumped for the intermediate water-use crop scenario and 350 feet pumping lift. This cost ranged from $0.87 for conventional furrow to $4.18 for subsurface drip. The fixed cost per acre-inch for LESA center pivot is estimated to be $1.92, including $1.06 for depreciation, $0.06 taxes, $0.16 insurance and $0.64 interest.

The assumptions used in the fixed-cost calculations are presented in Appendix A, Table 2.

Variable pumping costs

Variable costs include fuel, lubrication, maintenance, repairs and labor. Fuel costs are based on natural gas priced at $2.71 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 $8 per hour.

Table 4 shows the variable pumping costs in dollars per acre-inch of water pumped for the six irrigation systems at 350 feet pumping lift.

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

			acre-inches		
Irrigation System	Application Efficiency (%)	Application Efficiency Index	High Water Use	Intermediate Water Use	Low Water Use
CF	60	1.47	29.40	20.58	11.76
SF	75	1.17	23.40	16.38	9.36
MESA	78	1.13	22.60	15.82	9.04
LESA	88	1.00	20.00	14.00	8.00
LEPA	95	0.93	18.60	13.02	7.44
SDI	97	0.91	18.20	12.74	7.28

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

	dollars/acre-inch of water					
Cost Component/System	CF	SF	MESA	LESA	LEPA	SDI
A. Fixed cost						
Depreciation	0.32	0.45	0.76	1.06	1.22	2.09
Taxes	0.02	0.02	0.04	0.06	0.06	0.13
Insurance	0.05	0.07	0.13	0.16	0.17	0.39
Interest charges	0.48	0.68	0.52	0.64	0.70	1.57
Total fixed costs	0.87	1.22	1.45	1.92	2.15	4.18
B. Variable costs						
Fuel costs	2.73	2.73	2.98	2.81	2.81	2.81
LMR[1] charges	1.80	1.82	2.10	2.03	2.05	2.17
Labor costs	0.92	0.73	0.70	0.62	0.57	0.56
Total variable costs	5.45	5.28	5.78	5.46	5.43	5.54
Total fixed and variable cost (A+B)	6.32	6.50	7.23	7.38	7.58	9.72

[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 $6.32 per acre-inch; subsurface drip had the highest cost at $9.72 per acre-inch. MESA, LESA and LEPA center pivot systems ranged from $7.23 to $7.58 per acre-inch.

Total pumping cost

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

For the intermediate water use scenario, LEPA center pivot had the lowest annual pumping cost, $98.69 (13.02 acre-inches x $7.58 per acre-inch), because of its high application efficiency. Conversely, conventional furrow irrigation, which had the lowest pumping cost per acre-inch ($6.32), had the highest total annual pumping cost $130.07 (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 350-foot pumping lift for three crop scenarios and six irrigation systems.

	dollars/acre		
System/ Water Use	High Water Use	Intermediate Water Use	Low Water Use
CF	169.34	130.07	85.02
SF	138.29	106.47	71.51
MESA	148.03	114.38	78.11
LESA	130.60	103.32	72.88
LEPA	124.81	98.69	70.83
SDI	149.06	123.83	96.61

Savings from field operations and total annual irrigation

Center pivot and subsurface drip irrigation systems require fewer field operations than do furrow or surge flow irrigation. For example, the field operations commonly used to produce corn under furrow or surge flow 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 $5 per operation, the estimated savings are $20 per acre.

The number of field operations performed or saved varies considerably, depending on the cropping system, growing conditions for a particular year and the crop planted. Corn producers have indicated that anywhere from four to six field operations may be saved under center pivot or subsurface drip irrigation, amounting to $20 to $30 per acre. Typically, three field operations are eliminated for sorghum, soybeans and cotton production, saving $15 per acre (Table 6).

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

	dollars/acre		
System	Savings in Pumping Cost	Savings from Field Operations	Annual Irrigation Savings
CF	0.00	0.00	0.00
SF	23.60	0.00	23.60
MESA	15.69	15.00	30.69
LESA	26.75	15.00	41.75
LEPA	31.37	15.00	46.37
SDI	6.23	15.00	21.23

Cost/Benefit Analysis

The net investment cost and benefits of adopting efficient irrigation technology at 350-foot pumping lifts for high, intermediate and low water-use crop scenarios are presented in Table 7.

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. For example, the benefits for the high water-use scenario (corn) for surge flow are $396.92 per acre in current dollars over 25 years.

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 conventional furrow system to a LEPA center pivot system

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

	dollars/acre				
			Net Benefits		
System	Net Investment Cost	Change in Net Investment[1]	High Water Use	Intermediate Water Use	Low Water Use
CF	152.63				
SF	171.11	18.48	396.92	301.63	172.76
MESA	252.37	99.74	528.13	392.28	280.20
LESA	268.05	115.42	750.95	533.65	347.00
LEPA	277.73	125.10	825.02	592.82	373.22
SDI	614.71	462.08	514.99	271.43	43.71

[1]Change in net investment cost from furrow.

reveals that LEPA requires an additional net investment of $125.10 per acre; however, the reduction in field operations and pumping costs would save $825.02 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 $373.22 per acre compared to the $125.10 per acre of additional investment.

A similar evaluation can be made of the other systems using Table 7. For example, comparing MESA and LESA center pivots indicates that the net investment would increase $15.68 per acre (from $252.37 to $268.05) if a LESA system was purchased instead of MESA. However, assuming an intermediate water-use level, the increase in benefits of $141.37 ($392.28 to $533.65) per acre far outweighs the cost.

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 feasability.

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

- Adding surge valves to a conventional furrow irrigation system is cost effective if a producer can overcome the assorted management problems.
- It appears that the water and/or field operation savings justify converting furrow or MESA irrigation systems to LESA or LEPA center pivots whenever physically possible.
- Converting to drip irrigation is not feasible based on water and field operation savings.

The study did not address the potential yield increases of making more frequent water applications to the crop 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. It is important to understand how 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 six irrigation systems. The fuel costs were estimated using natural gas prices ranging from $3.00 to $8.00 per MCF in increments of $1.00.

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 $3.00 to $8.00 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 with higher application efficiencies.

For example, at $3.00 per MCF, a producer would save $30.76 per acre (a decrease from $88.79 to $58.03 per acre) by using LEPA center pivot instead of conventional furrow. At $8.00 per MCF, the savings would increase to $82.39 (from $154.57 to $236.96) per acre.

This is the result of fuel costs increasing by $148.17 (from $88.79 to $236.96) per acre for furrow, while LEPA increases by only $96.54 (from $58.03 to $154.57) 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.

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 an LEPA center pivot at 250-foot pumping lift was $42.97; at 550 feet, the cost was $61.94, an increase of $18.97 per acre of irrigated corn. For that system, fuel cost increased by 44 percent as pumping lift increased from 250 feet to 550 feet.

Table 8. Estimated fuel costs for effective irrigation water applied to 1 acre of irrigated corn at alternative gas prices for six irrigation systems at 350-foot lift.

Gas Price ($/MCF)		3	4	5	6	7	8
Irrigation System	Water Applied acre-inch	Fuel Costs ...dollars per acre...					
CF	29.40	88.79	118.48	148.18	177.58	207.27	236.96
SF	23.40	70.67	94.30	117.94	141.34	164.97	188.60
MESA	22.60	74.58	99.44	124.30	149.39	174.25	199.11
LESA	20.00	62.40	83.00	103.80	124.60	145.40	166.20
LEPA	18.60	58.03	77.19	96.53	115.88	135.22	154.57
SDI	18.20	56.78	75.53	94.46	113.39	132.31	151.24

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

Pumping Lift		150’	250’	350’	450’	550’
Irrigation System	Water Applied acre-inches	dollars per acre				
CF	29.40	46.75	65.27	80.26	86.73	95.84
SF	23.40	37.21	51.95	63.88	69.03	76.28
MESA	22.60	43.17	56.50	67.35	73.22	78.20
LESA	20.00	34.00	46.20	56.20	60.40	66.60
LEPA	18.60	31.62	42.97	52.27	56.17	61.94
SDI	18.20	30.94	42.04	51.14	54.96	60.61

[1]Natural gas price of $2.71 per MCF was assumed.

For conventional furrow, the pumping cost was $65.27 at 250 feet and $95.84 at 550 feet. This was an increase of $30.57 per acre, which was $11.60 more than LEPA center pivot. The fuel costs for each irrigated acre of corn were $80.26 and $52.27 at 350-foot pumping lift using conventional furrow and LEPA center pivot, respectively.

At 350-foot pumping lift, producers will be able to save about $28.00 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 $33.90 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.

Amount of water pumped affects 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 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 (Figure 9). 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 $5.31; for conventional furrow, the fixed cost was $1.76. However, as the amount of water pumped increased to 30 acre-inches, the fixed cost dropped to $1.77 for subsurface drip and to $0.59 for con-

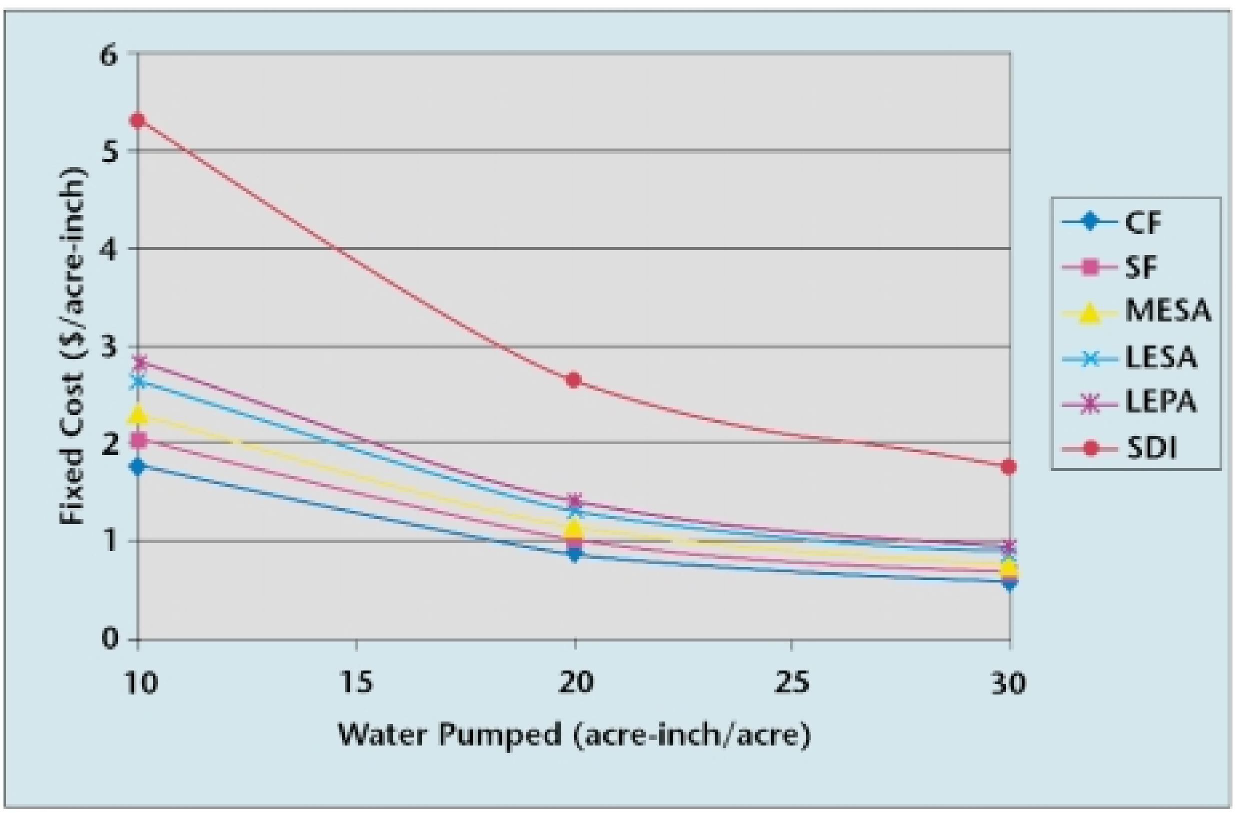

Figure 9. Changes in fixed cost as affected by the amount of water pumped in six types of irrigation systems.

ventional furrow. Therefore, the difference in fixed cost of the systems narrowed significantly, from $3.55 per acre-inch (from $5.31 to $1.76) to $1.18 per acre-inch ($1.77 to $0.59) as use increased from 10 to 30 acre-inches per year.

For MESA, LESA and LEPA center pivots, the fixed cost per acre-inch ranged from $2.31 to $2.83 for 10 acre-inches and decreased to $0.77 and $0.94 for 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 six irrigation systems (Table 10). Labor costs at $12 per hour using conventional furrow and LEPA center pivot were $28.35 and $11.29 per acre, respectively. By switching to more a efficient irrigation system, growers can reduce labor costs by $17.06 for each acre irrigated annually.

The savings in labor cost by shifting from conventional furrow to LEPA center pivot increases to $22.75 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.

Additional benefits from fertigation and chemigation

Applying fertilizers with irrigation waters is called fertigation. Most fertigation uses soluble or liquid formulations of nitrogen, phosphorus and potassium. Fertigation can easily be accomplished by using any of the irrigation technologies considered.

Fertigation has many benefits, including:

- Nutrients can be applied uniformly and at any time during the growing season as needed by the crop, thus maximizing the effectiveness of the fertilizer.
- It can reduce application costs and eliminate some of the tillage operations performed to incorporate fertilizer.
- The threat of groundwater contamination and crop "burn" is decreased when smaller but more frequent applications of fertilizer are made.

Chemigation is the application of an approved chemical (herbicide, insecticide, fungicide or nematicide) with irrigation water through an irrigation system. Chemigation is a cost-effective management tool for crop production. Approved systematic chemicals can be used in all six of the irrigation systems evaluated, reducing application costs.

However, center pivot has a distinct advantage over the other systems considered because it is flexible enough to apply chemicals that must reach the crop canopy.

Chemigation through center pivot has many advantages over ground or aerial application, including uniform and precise application, cost saving, operator safety and the need for potentially smaller amounts of chemicals while achieving the same level of control. Also, environmental contamination may be reduced because there is less drift with chemigation than with aerial or ground-sprayer applications.

Chemigation makes irrigation more economically feasible. The cost of applying chemicals through an irrigation system is one-third to one-half as much as from aircraft or tractors.

However, chemigation requires skill in calibration, knowledge of the irrigation and chemigation equipment, and understanding of chemical and irrigation scheduling.

Table 11 gives an example of the costs of applying chemicals using an LEPA center pivot system compared to aerial or ground application. When using conventional application methods, the costs range from $3.16 to $6.32; the costs using LEPA center pivot for chemigation range from $1.17 to $2.34.

The costs drop significantly as the number of annual applications increase. Producers can save from $1.99 to $3.98 per acre when using center pivot for chemigation. This finding suggests that producers can save even more by applying chemicals through advanced irrigation technology such as center pivot.

Study limitations

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

First, researchers considered only one method of improving the application efficiency of conventional furrow irrigation systems: the addition of a surge valve. A second way to improve the application efficiency of conventional furrow is to

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

Wage Rate ($/Hour)		8	10	12	14	16
Irrigation System	Water Applied acre-inches	Labor Cost dollars per acre				
CF	29.40	18.90	23.63	28.35	33.08	37.80
SF	23.40	11.93	14.91	17.89	20.88	23.86
MESA	22.60	11.12	13.90	16.68	19.46	22.24
LESA	20.00	8.70	10.88	13.05	15.23	17.40
LEPA	18.60	7.53	9.41	11.29	13.17	15.05
SDI	18.20	7.21	9.01	10.81	12.62	14.42

Table 11. Variable cost savings of chemigation through LEPA versus aerial application.

	dollars per acre					
	.... One Annual Application			............Two Annual Applications		
Variable Cost Item	Aerial/Conventional	LEPA	Saving	Aerial/Conventional	LEPA	Saving
Application cost	3.00	0.67	2.33	6.00	1.34	4.66
Labor	0.00	0.12	(0.12)	0.00	0.24	(0.24)
Repairs	0.00	0.32	(0.32)	0.00	0.64	(0.64)
Interest (10.5 %, 6 mo)	0.16	0.06	0.10	0.32	0.12	0.20
Total variable cost	3.16	1.17	1.99	6.32	2.34	3.98

add a tailwater recovery system. This involves building a tailwater pit to hold excess runoff and buying a pump and underground line to recirculate the water to the top of the field.

Depending on the topography and soil type of the field, producers can increase application efficiency from 60 percent to 80 percent by adding a tailwater recovery system.

Another 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 that may be obtained through more frequent irrigations that can result through center pivots and especially SDI as compared to conventional 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, field topography, etc.

Overlaying these factors are the differences in the cost 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 six commonly used irrigation systems in Texas: conventional furrow, surge flow, 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 requires less capital investment but has lower water application efficiency and is more labor intensive than the other irrigation systems.
- Adding surge flow valves increases water application efficiency enough to increase returns per acre. However, before purchasing surge equipment, growers should closely evaluate the ability to provide the required constant management of irrigation scheduling with surge flow systems.
- Compared to furrow irrigation, center pivots 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.
- Among the three center pivot alternatives, LEPA center pivot generates 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 chemigation and the need for fewer field operations.
- Compared to LEPA center pivot, 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.

For More Information

B-1241, "Crop and Livestock Enterprise Budgets, Texas High Plains, Projected for 2000," Texas Cooperative Extension.

B-6096, "Center Pivot Irrigation," Texas Cooperative Extension.

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Appendix

Table 1. Estimated gross investment costs (in dollars) for alternative irrigation systems at five pumping lifts in Texas.

Irrigation System/Lift (feet)	Well	Pump	Engine	Sprinkler Heads	Distribution System	Total
CF						
150’			2,800		26,450	29,250
250’	18,700	14,040	3,500		26,450	29,950
350’	23,625	19,610	5,000		26,450	31,450
450’	28,000	23,520	5,500		26,450	31,950
550’	34,312	29,315	20,000		26,450	46,450
SF						
150’			2,800		29,650	32,450
250’	18,700	14,040	3,500		29,650	33,150
350’	23,625	19,610	5,000		29,650	34,650
450’	28,000	23,520	5,500		29,650	35,150
550’	34,312	29,315	20,000		29,650	49,650
MESA						
150’			2,800	1,710	41,000	45,510
250’	18,700	14,040	3,500	1,710	41,000	46,210
350’	23,625	19,610	5,000	1,710	41,000	47,710
450’	28,000	23,520	5,500	1,710	41,000	48,210
550’	34,312	29,315	20,000	1,710	41,000	62,710
LESA						
150’			2,800	4,863	41,000	48,663
250’	18,700	14,040	3,500	4,863	41,000	49,363
350’	23,625	19,610	5,000	4,863	41,000	50,863
450’	28,000	23,520	5,500	4,863	41,000	51,363
550’	34,312	29,315	20,000	4,863	41,000	65,863
LEPA						
150’			2,800	6,000	41,000	49,800
250’	18,700	14,040	3,500	6,000	41,000	50,500
350’	23,625	19,610	5,000	6,000	41,000	52,000
450’	28,000	23,520	5,500	6,000	41,000	52,500
550’	34,312	29,315	20,000	6,000	41,000	67,000
SDI						
150’			2,800		133,157	135,957
250’	18,700	14,040	3,500		133,157	136,657
350’	23,625	19,610	5,000		133,157	138,157
450’	28,000	23,520	5,500		133,157	138,657
550’	34,312	29,315	20,000		133,157	153,157

Table 2. Useful life and salvage value assumptions used to calculate depreciation of six irrigation systems.

Item/Component	Useful Life (years)	Salvage value (%)
Furrow /surge flow	25	0
Center pivot	25	20
Sprinkler heads	8	10
Subsurface drip	25	20

Table 3. Fixed cost for irrigating at three levels of water use under six irrigation systems.

System/Water Use	Depreciation	Taxes	Insurance	Interest	Total
	. . . . dollars/acre inch				
CF					
High	0.22	0.01	0.03	0.34	0.60
Intermediate	0.32	0.02	0.05	0.48	0.87
Low	0.56	0.03	0.08	0.84	1.51
SF					
High	0.32	0.02	0.05	0.48	0.87
Intermediate	0.45	0.02	0.07	0.68	1.22
Low	0.79	0.04	0.12	1.19	2.14
MESA					
High	0.53	0.03	0.09	0.37	1.02
Intermediate	0.76	0.04	0.13	0.52	1.45
Low	1.33	0.07	0.23	0.91	2.54
LESA					
High	0.74	0.03	0.11	0.44	1.32
Intermediate	1.06	0.06	0.16	0.64	1.92
Low	1.86	0.09	0.28	1.11	3.34
LEPA					
High	0.85	0.05	0.13	0.49	1.52
Intermediate	1.22	0.06	0.17	0.70	2.15
Low	2.14	0.10	0.30	1.23	3.77
SDI					
High	1.46	0.09	0.27	1.10	2.92
Intermediate	2.09	0.13	0.39	1.57	4.18
Low	3.66	0.23	0.69	2.74	7.32

Table 4. Variable costs (dollars per acre-inch) for a high water-use crop (corn) for six irrigation systems at five lifts.

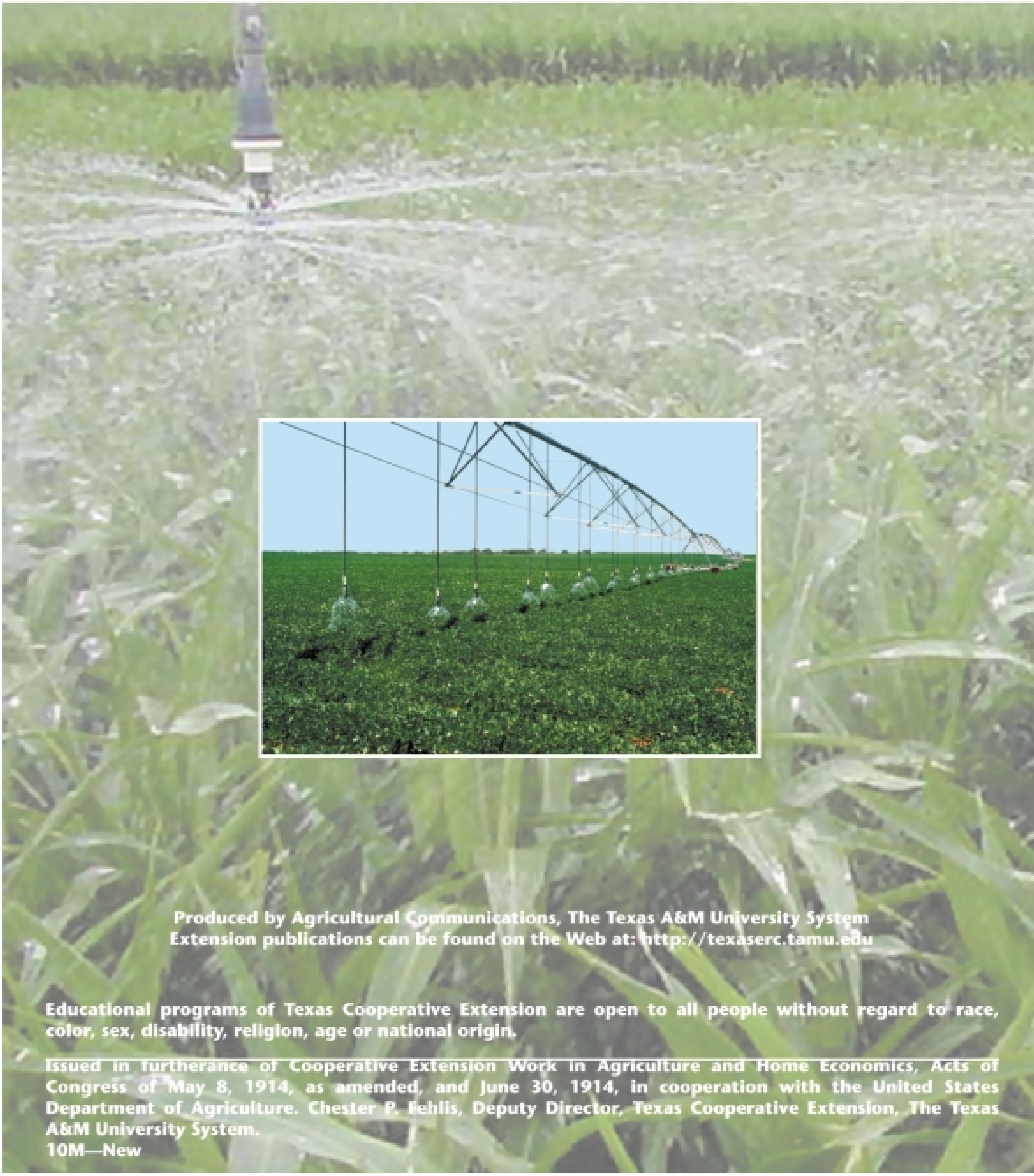
	dollars/acre-inch			
System/Lift	Fuel	LMR	Labor	Total
CF				
150’	1.59	1.05	0.64	3.28
250’	2.22	1.46	0.64	4.32
350’	2.73	1.79	0.64	5.16
450’	2.95	1.94	0.64	5.53
550’	3.26	2.14	0.64	6.04
SF				
150’	1.59	1.06	0.51	3.16
250’	2.22	1.47	0.51	4.20
350’	2.73	1.80	0.51	5.04
450’	2.95	1.95	0.51	5.41
550’	3.26	2.15	0.51	5.92
MESA				
150’	1.91	1.36	0.49	3.76
250’	2.50	1.75	0.49	4.74
350’	2.98	2.06	0.49	5.53
450’	3.24	2.23	0.49	5.96
550’	3.46	2.37	0.49	6.32
LESA				
150’	1.70	1.25	0.43	3.38
250’	2.31	1.64	0.43	4.39
350’	2.81	1.97	0.43	5.21
450’	3.02	2.10	0.43	5.56
550’	3.33	2.30	0.43	6.07
LEPA				
150’	1.70	1.25	0.41	3.36
250’	2.31	1.65	0.41	4.37
350’	2.81	1.97	0.41	5.19
450’	3.02	2.11	0.41	5.54
550’	3.33	2.31	0.41	6.05
SDI				
150’	1.70	1.35	0.39	3.44
250’	2.31	1.75	0.39	4.45
350’	2.81	2.07	0.39	5.27
450’	3.02	2.21	0.39	5.62
550’	3.33	2.41	0.39	6.13

Table 5. Variable costs (dollars per acre-inch) for an intermediate water-use crop (sorghum/soybeans) for six irrigation systems at five lifts.

	dollars/acre-inch			
System/Lift	Fuel	LMR	Labor	Total
CF				
150’	1.59	1.06	0.92	3.57
250’	2.22	1.47	0.92	4.61
350’	2.73	1.80	0.92	5.45
450’	2.95	1.95	0.92	5.82
550’	3.26	2.15	0.92	6.33
SF				
150’	1.59	1.08	0.73	3.40
250’	2.22	1.49	0.73	4.44
350’	2.73	1.82	0.73	5.28
450’	2.95	1.97	0.73	5.65
550’	3.26	2.17	0.73	6.16
MESA				
150’	1.91	1.40	0.70	4.01
250’	2.50	1.79	0.70	4.99
350’	2.98	2.10	0.70	5.78
450’	3.24	2.27	0.70	6.21
550’	3.46	2.41	0.70	5.57
LESA				
150’	1.70	1.31	0.62	3.63
250’	2.31	1.70	0.62	4.63
350’	2.81	2.03	0.62	5.46
450’	3.02	2.16	0.62	5.81
550’	3.33	2.36	0.62	6.32
LEPA				
150’	1.70	1.33	0.58	3.61
250’	2.31	1.72	0.58	4.61
350’	2.81	2.05	0.58	5.44
450’	3.02	2.18	0.58	5.78
550’	3.33	2.38	0.58	6.29
SDI				
150’	1.70	1.45	0.57	3.72
250’	2.31	1.84	0.57	4.72
350’	2.81	2.17	0.57	5.55
450’	3.02	2.30	0.57	5.89
550’	3.33	2.50	0.57	6.40

Table 6. Variable costs (dollars per acre-inch) for a low water-use crop (cotton) for six irrigation systems at five lifts.

System/Lift	dollars/acre-inch			
	Fuel	LMR	Labor	Total
CF				
150’	1.59	1.08	1.16	3.83
250’	2.22	1.49	1.16	4.87
350’	2.73	1.82	1.16	5.72
450’	2.95	1.97	1.16	6.08
550’	3.26	2.17	1.16	6.59
SF				
150’	1.59	1.11	0.92	3.62
250’	2.22	1.52	0.92	4.66
350’	2.73	1.85	0.92	5.50
450’	2.95	2.00	0.92	5.87
550’	3.26	2.20	0.92	6.38
MESA				
150’	1.91	1.53	0.89	4.33
250’	2.50	1.91	0.89	5.30
350’	2.98	2.23	0.89	6.10
450’	3.24	2.39	0.89	6.52
550’	3.46	2.54	0.89	6.89
LESA				
150’	1.70	1.45	0.79	3.94
250’	2.31	1.85	0.79	4.95
350’	2.81	2.17	0.79	5.77
450’	3.02	2.31	0.79	6.12
550’	3.33	2.51	0.79	6.63
LEPA				
150’	1.70	1.49	0.73	3.92
250’	2.31	1.88	0.73	4.92
350’	2.81	2.21	0.73	5.75
450’	3.02	2.34	0.73	6.09
550’	3.33	2.54	0.73	6.61
SDI				
150’	1.70	1.70	0.72	4.12
250’	2.31	2.10	0.72	5.13
350’	2.81	2.43	0.72	5.95
450’	3.02	2.56	0.72	6.30
550’	3.33	2.76	0.72	6.81



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