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Economic Evaluation of Subsurface and Center Pivot Irrigation Systems[1]

by

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ABSTRACT

Two alternative irrigation systems were evaluated using present value analysis to show the economic benefits (or costs) of each system. A center-pivot system and a subsurface (controlled and reversible drainage) system on nearby farms in Orangeburg County, S.C, were studied. Initial system costs were obtained in addition to two years' operating costs and benefits, with corn as the crop grown. For the conditions of this study the subsurface system was found to be a more profitable investment than the center-pivot system.

Introduction

As the irrigation and drainage of agricultural lands becomes more widespread in the Southeast Coastal Plain, the information needed to better determine the profitability of agricultural irrigation and/or drainage systems is becoming more readily available. Farmers and investors need to utilize all available information in making a thorough economic evaluation of an irrigation system before investing. They should ask whether an investment in a system will be a profitable one. Will the gains from increased yields or reduced risks be sufficient to offset the added costs? This paper presents an economic evaluation of two different types of irrigation systems using the present value method of analysis.

Background

The two methods of irrigation analyzed in this study are center-pivot and subsurface (controlled and reversible drainage system - CaRDS). Center-pivot irrigation is used in the economic comparison since it is a popular, rapidly increasing method of irrigating in the

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South Carolina coastal plains. CaRD systems are limited to a few thousand acres in South Carolina but are on the increase.

Several investigators have reported on the design and operation of subsurface irrigation or CaRD systems (2, 3, 4, 5, 6, 9, 10, 12). Massey, et al., (7) reported a study of energy requirements of subirrigation versus sprinkler systems. Strickland, et al., (11) presented data on water and energy use by the two types of systems. However, little has been reported concerning their relative economic aspects.

The systems selected for evaluation in this study are located in Orangeburg County, South Carolina. A 49.8 hectare center-pivot system and a 22.7 hectare CaRDS system were selected because of their proximity to each other and the similarity in farming practices by the two owners. Owner management and operation of the systems was maintained throughout the two-year study period, 1980-81.

Center-Pivot - The center pivot system used in the study covered 44.5 hectares in 1980 but the partial circle was expanded to cover 49.8 hectares in 1981. The system was designed and operated to apply 1.9 cm of water per application. Water is supplied by a well 300 meters deep with a pumping rate of 0.19 m^3/s and located outside the irrigated field. Power for pumping is supplied by a diesel engine while the system itself is moved by electricity supplied from power company lines.

CaRD System - The CaRD system studied covers 22.7 hectares and consists of an open 671-meter ditch running through the center of the field with 10 cm corrugated plastic tile lines spaced 30.5 meters apart extending perpendicular to the ditch on either side. Control structures are located at both ends of the field ditch to allow for water level adjustments within the field. Water is supplied by a 150 meter deep well with a pumping rate of 0.13 m^3/s and is delivered to the field via open supply ditches. One lift pump is needed to help move water through the series of supply ditches to the controlled ditch in the field. In 1980 a gasoline powered pump provided the lift. In 1981 the supply system was changed and an electrically powered lift pump used.

Other characteristics of the two systems being studied have been reported by Strickland, et al., (11).

Data

Data were gathered on corn crops for two growing seasons, 1980 and 1981. Measurements made at each site were:

1. precipitation,
2. evaporation,
3. water flowing to the system,
4. water table levels (for CaRDS only),
5. fuel and electricity usage,
6. times and durations of system operation, and
7. crop yields from irrigated, and nonirrigated plots

In addition to this operating information, historical records were established to show dates and cost of construction of each system.

Summaries of the data compiled for use in a present value analysis are presented in Tables 1 - 3. These tables give initial costs, operating and maintenance costs and yield information needed to determine economic benefits of the systems.

Table 1. Water and Energy Requirements for Irrigation.

	Subsurface		Center-Pivot	
	1980 (22.7 ha)	1981 (22.7 ha)	1980 (44.5 ha)	1981 (49.8 ha)
Water pumped (cm)	20.5	12.5	16.8	12.5
Energy usage				
Electricity (kilowatt hrs)	4240	4231	650	366
Diesel (liters)	-	-	21,103	11,870
Gasoline (liters)	1259	-	-	-

Table 2. Annual Cost of Irrigating One Hectare[1,2].

	Subsurface		Center-Pivot	
	1980	1981	1980	1981
Annual fixed cost				
Depreciation	$45.00	$45.00	$85.84	$85.84
Other (base electric charge)[3]	5.51	5.51	0.00	0.00
Total	$50.51	$50.51	$85.84	$85.84
Annual operating costs				
Fuel	$33.67	$17.59	$48.07	$27.00
Oil	1.06	0.17	2.89	2.20
Repairs	5.58	4.99	9.27	7.82
Labor for operation	0.69	0.54	0.17	0.12
Additional production costs	0.00	0.00	48.17[4]	48.71[4]
Total	$41.00	$23.24	$108.57	$85.31
Annual cost of irrigating				
Annual fixed cost	$50.51	$50.51	$85.04	$85.04
Annual operating cost	41.00	23.24	108.57	85.31
Total/Hectare	$91.51	$73.75	$193.61	$170.35

1) Insurance, taxes and money costs are omitted because of variability due to owner preference and different loan interest rates applicable to each system. In 1981, the subsurface qualified for a long term 11 1/4% loan while the center-pivot qualified for a shorter term 14% rate only.

2) All costs except oil and repairs are actual costs. Costs for oil and repairs were estimated using formulas presented by Jordan and Smith, p. 20, in Privette, et al., (8).

3) Applies only to the first 5 years of operation.

4) Cost of additional N fertilizer supplied through the center-pivot system.

Table 3. Summary of Yields (Metric Tons/Hectare).

	Subsurface		Center-Pivot	
	1980	1981	1980	1981
Irrigated yield	10.8	8.7	11.3	10.0
Nonirrigated yield	7.2	6.2	8.0	9.1
Yield increase due to irrigation	3.6	2.5	3.3	0.9
% Increase in yield over nonirrigated yield	51	40	41	10

Analysis

Present value analysis was used to evaluate each irrigation system. For conducting the analysis the following information was needed (1):

1. initial costs less investment tax credit,
2. annual cash flows for each alternative,
3. salvage value,
4. term of the analysis, and
5. discount rate.

The determination of each of these is explained below.

Initial costs for the components of each system were obtained from owner's records and are summarized in Table 4. Since the study began in 1979, costs are presented in terms of 1979 dollars. When components were purchased prior to 1979 (as was the case for the center-pivot system) original costs were inflated at a rate of 5% per year. Once all costs were in terms of 1979 dollars, further adjustments were made when a system component serviced a total area greater than the study area. Examples of components servicing larger areas are the wells in both systems. For the CaRD system, the well provides water to irrigate 162 hectares, part of which is the 22.7 hectare study field. The adjusted initial cost of the center-pivot system was $1410.76/ha ($570.93/ac) while that of CaRDS was $939.37/ha ($380.16/ac).

Investment tax credits were taken into consideration when computing net present value. A 10% tax credit was applied to the portion of the initial investment qualifying for such a credit. The result was a $5,443.08 tax credit for the center-pivot system and a $1,438.05 tax credit for the CaRD system.

Annual cash flow incorporates an annual calculation of the net benefits of irrigating, i.e., the $ benefit from additional sales minus the additional operating and maintenance costs and income tax. Operating and maintenance costs for the two systems being analyzed have already been summarized in Table 2. Income tax was determined using an assumed tax rate of 30% for each owner. Depreciation was taken into account when calculating income tax and was determined using the straight line method.

For components having a useful life greater than the 10-year term of the analysis, salvage value was assumed to be equal to the amount of unused depreciation. Salvage value was $11,116.81 for the CaRD system and $27,387.29 for center-pivot.

Term of the analysis, as already mentioned, was chosen to be 10 years. This length of time was selected because it corresponds to the

Table 4. Summary of Initial Costs.

System	Component	1977 Cost	1979 Cost[1]	Cost Distribution Factor[2]	Applicable Cost for Component
CaRDS	Well		25,700.00	.140	3,598.00
	Pump, 100 hp		14,407.00	.140	2,016.98
	Small Pump, 8 hp		835.00		835.00
	Supply Ditch		1,015.00		1,015.00
	Field Ditch		1,041.75		1,041.75
	Ditch Control Structures		1,150.00		1,150.00
	Drain Tile and Installation		11,213.50		11,213.50
	Land Planning		453.50		453.50
				Total Initial Cost	$21,323.73
				Initial Cost per ha	$ 939.37
Center Pivot	Center-Pivot System	32,000	35,280.00		35,280.00
	Supply pipe, Electrical Control Wire, Installation	10,000	11,025.00		11,025.00
	Well	50,000	55,125.00	.273	15,049.13
	Pump	12,000	13,230.00	.273	3,611.79
	Power Unit, 280 hp	15,000	16,537.50	.273	4,514.74
	Bridges	700	771.75		771.75
				Total Initial Cost	$70,252.41
				Initial Cost per ha	$ 1,410.76

1) A 5% per year inflation rate was used to update costs for the center-pivot system.
2) A cost distribution factor is used when an item services an area greater than the study areas. The factor is study area acreage ÷ total service area acreage.

shortest useful life of any of the components of either system. This 10-year analysis period (term) was used to avoid complicating calculations with replacement costs.

Discount rate selection for any present value analysis is a difficult task since it reflects the investor's opportunity cost and his aversion to risk. This study, therefore, applied various discount rates (from 2% to 28%) when determining net present value. This was done to show the impact of varying the discount rate on net present value of the investment.

In addition to the above information, assumptions made before analysis could be completed were:

1. a cash purchase for each system,
2. two-year average yields and average operating costs applicable throughout the 10-year term of the analysis,

3. annual cash flows constant for the 10 year period.

These assumptions were made so that each system was analyzed under similar conditions, therefore allowing comparison of the final results.

An example of the calculations necessary for determining net present value for each system is shown in Table 5. The observed two-year average yield increases (3.05 tons/ha for CaRDS and 2.10 tons/ha for center-pivot) were applied for all years of the analysis. A corn price of $118/ton was used to determine the dollar value of the additional grain sales. The discount rate used in the example in Table 5 was 14% and the net present value was determined to be $12,011.96 for CaRDS and -$23,356.63 for the center-pivot system.

Results and Conclusions

The net present values determined for various discount rates for each system studied are given in Table 6. Note that the center-pivot system has a negative net present value at all discount rates above

Table 5. Present Value Determination for CaRDS and Center-Pivot System for a 14% Discount Rate.

	CaRDS (22.7 ha)	Center-Pivot (49.8 ha)
1. Initial Project Cost	$21,323.73	$70,252.41
Income Tax Credit	- 1,438.05	- 5,443.08
Net Initial Cost	$19,885.68	$64,809.33
2. Calculations of Annual Benefits (1980-89)		
Additional Sales	8,206.80	12,324.60
Less: Operating Expenses	- 729.12	- 4,827.38
Depreciation	-1,020.17	- 4,274.66
Taxable Income	6,457.51	3,223.56
Less: Tax (at 30%)	-1,937.25	- 967.07
After Tax Profit	4,520.26	2,256.49
Plus: Depreciation	+1,020.17	+4,274.66
Cash Flow	$5,540.43	6,531.15
3. Present Value of Benefits	28,899.44	34,066.35
4. Present Value of Salvage	2,998.20	7,386.35
5. Net Present Value		
Annual Benefits	28,899.44	34,066.35
Plus: Salvage	+ 2,998.20	+ 7,386.35
	31,897.64	41,452.70
Less: Net Initial Cost	- 19,885.68	-64,809.33
Net Present Value	$12,011.96	-23,356.63

Table 6. Net Present Values for Investments in CaRDS and Center-Pivot Irrigation Systems for a Range of Discount Rates.

Discount Rate (%)	CaRDS	Center-Pivot
2		+ 16,323.16
3		+ 11,280.29
4		+ 6,665.81
5	29,720.47	+ 2,423.15
6	27,100.07	- 1,447.46
7	24,678.75	- 5,017.24
8	22,440.47	- 8,299.92
9	20,366.88	- 11,326.94
10	18,442.85	- 14,121.15
12	15,365.33	- 19,089.16
14	12,011.96	- 23,356.63
16	9,412.51	- 27,035.00
18	7,137.99	- 30,224.65
20	5,143.47	
24	1,807.63	
28	- 832.98	

5%. The CaRD system shows a positive net present value at all discount rates considered except 28%. At a discount rate of 27% the net present value approximately equals zero, indicating that the internal rate of return for the CaRD system investment is 27%. For the costs and yields observed in this study, the CaRD system is a more profitable investment than the center-pivot system.

Greater yield increases are needed to increase the profitability of the center-pivot system. To achieve a 14% rate of return on investment, a yield increase of 3.18 tons/ha is needed compared to the average increase of 2.10 tons/ha observed in this study. Privette, et al. (8) suggest that even greater yield increases are needed for center-pivot irrigation to be profitable.

Strickland et al. (11) presented advantages and disadvantages of the center-pivot and CaRD systems. To their list of disadvantages to the center-pivot system should be added the higher initial and operating costs. The CaRD system on the other hand appears to have an economic edge with its lower initial and operating costs.

Use of subsurface irrigation systems is limited to geographical areas where land surfaces are relatively flat, water tables are naturally high, and where soil permeabilities are satisfactory for easy movement of moisture within the plant root zone. It should be noted, however, that the CaRD system also functions as a drainage system when needed, and that the cost of the drainage function is included in system costs as used in this analysis. If subsurface drainage were needed under the center-pivot system, additional expenditures would be required.

Conclusions should be drawn from this study with care since only one system of each type was analyzed. The CaRDS system is believed to be fairly typical of such systems which have been or could be installed in the Southeast Coastal Plains. However, significant variations in costs can be expected depending upon soil conditions, topography and source of the water supply.

Similarly, considerable variation in costs of center-pivot systems occur. The system studied was relatively small (49.8 ha) and covered only about three-fourths of a full circle. Therefore, cost per hectare of the center-pivot system itself was relatively high. On the other hand, this system shared a well, pump, and power unit with another, larger, center-pivot (combined area 182 ha) so that the costs per hectare of these components were relatively low.

The yield increases for irrigation considered in the economic analyses were based on two years of actual farm data. Long-term average yield increases could vary significantly. Average rainfall for the two years for the period April-July was 38 cm at the CaRDS site and 40 cm at the center-pivot site. Based on analysis of 22 years of precipitation data at a nearby station, rainfall totals less than these average amounts would be expected to occur about 3 years out of 10. Thus direct benefits greater than the two-year averages used might be expected about 1/3 of the time while lesser benefits might be expectd about 2/3 of the time.

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