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Economic Considerations for Florida Citrus Irrigation Systems [1]

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An economic analysis of alternatives is essential if maximum profits are to be achieved from a citrus irrigation system in Florida. A complete economic analysis includes an estimate of the initial investment required and annual costs and returns, including financing costs. Decisions on what system to use, how to modify existing systems, and when to replace components of an existing system should all be evaluated on a technical as well as an economic basis. The profitability of an irrigation investment calculation greatly depends upon engineering estimates of the life expectancy of the equipment, energy usage, and the maintenance and repairs required in operating the equipment. Labor requirements should also be determined and evaluated relative to current and future availabilities.

Contingencies can also have an important influence upon the profitability of an irrigation decision. For example, it is necessary to consider the level of management required and to evaluate the implications of failure to maintain the assumed level of management. Similar considerations apply to possible equipment breakdowns and the availability of parts and service. System costs may change dramatically, depending on the flexibility of the system. For example, a system that is designed for freeze protection will have a considerably higher per-acre cost than a zoned system.

Annual Ownership Costs

Annual irrigation costs include annual ownership costs and annual operating costs. Annual ownership costs include all costs that are associated with ownership and generally do not depend upon the level of use. These costs include the decrease in value of the initial investment due to age and obsolescence. Ownership costs also include an opportunity cost to reflect the returns that could be earned from the funds invested elsewhere. Other ownership costs include taxes and insurance.

The most accurate procedure for estimating average annual costs is to estimate the cash flows (out of pocket costs) for each year and determine the average annual equivalent by first discounting (finding the present value of) each cash cost and then using an amortization (or cost recovery) factor to determine the equivalent average annual cost. To be accurate, however, this method requires an estimate

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of all cash costs each year, including repairs, and many of these estimates are not readily available on an annual basis. As a result, the average annual costs are typically estimated from simple averages rather than derived from discounted annual cash flows.

Depreciation

Depreciation provides for the recovery of the initial investment over the investment period. Average annual depreciation is calculated by estimating the amount an asset will decline in value during its period of use and dividing by the years of use. The formula for average annual depreciation is:

$$\boxed{D_{avg} = \frac{Cost_1 - Salvage}{n}}$$

Equation 1.

where

D_{avg} = average annual depreciation

$Cost_1$ = purchase cost

Salvage = salvage value after n years

n = number of years the system is used

The salvage value is the value of the asset at the end of its use whether traded-in for replacement equipment or scrapped. The trade-in or scrap value of a piece of equipment can depend both upon the annual level of use and the number of years of use. The number of years of use depends upon replacement decisions. The value of the asset at the end of its useful life can be positive, zero or even negative if additional expenditure would be required to inactivate the system.

Table 1 lists typical useful life and annual maintenance costs for various microirrigation system components that have been tabulated from various sources. Considerable variability can occur for many of these components due to different physical conditions, repair level, operation and maintenance practices, and the amount of time the system is used each year. Lower expected life times are generally used for smaller units and are based on normal operation and maintenance practices that have generally occurred with their use. The upper ranges of life expectancy are suggested as guidelines for well-engineered, carefully constructed and maintained systems.

Careful judgement should be used when applying depreciation and life values during the economic analysis. If the depreciation period is based on an average usage of 1,000 hours per year, factors such as higher or lower hours of operation and level of maintenance will affect the life of a particular component in the irrigation system and, hence, the rate of depreciation.

Example:

Determine the average annual depreciation for a coated steel screen filter with a new cost of $8,000, a salvage value of $500, and an estimated useful life of 10 years.

Using Equation 1,

$$D_{avg} = \frac{\$8{,}000 - \$500}{10} = \$750 \; per \; year$$

The estimated useful life for each of the system components assumes considerable annual use of the equipment. The pump and power unit would have a longer life expectancy in systems designed to water all trees at once for freeze protection than in systems where the pump station serves several zones that are run independently.

There are many factors to be considered in determining the depreciation period and salvage value. Operating conditions, care, and maintenance, as well as wet-season operation, are contributing factors to the life of the equipment and should be considered when determining the rate of depreciation and salvage value.

Productive life expectancies and salvage values of irrigation system components are also influenced by replacement policy and the rate of development of new technology. Where frequent replacement is practiced to avoid breakdowns, the years of use will be shortened and salvage values increased. However, as new technology becomes available, equipment may be replaced more often, but salvage values may fall as new technologically enhanced components render older, even well-maintained, components obsolete.

Opportunity Costs

Accurate costing of resources used includes accounting for the value of funds invested. The economic cost, or opportunity cost, of any resource in producing a good is its value or worth in its best alternative use. A useful procedure to follow in calculating opportunity costs is to determine the returns that could be earned from the funds if invested elsewhere. For investments that have an indefinite useful life, the annual opportunity cost is estimated by multiplying the primary interest rate by the purchase price. The average cost of funds invested (Equation 2) in depreciable items can be estimated by multiplying the average annual investment times the annual interest rate. The average annual investment (Equation 3) is a simple average of the initial value of the investment (the purchase cost) and the value of the investment at the beginning of the last year of use (salvage value + average annual depreciation).

$$ACFI = AAI \ x \ i$$

Equation 2.

where

ACFI = Average Cost of Funds Invested (Average Opportunity Cost)

i = Primary Interest Rate

$$AAI = \frac{Cost_1 + \left(Salvage + D_{avg}\right)}{n}$$

Equation 3.

where

AAI = Average Annual Investment

<u>Example</u>:

Determine the average opportunity cost of funds invested from the previous example.

Using Equation 3,

$$AAI = \frac{\$8{,}000 + (\$500 + \$750)}{10} = \$925 \ per \ year$$

Using Equation 2,

$$ACFI = \$925 \ x \ .06 = \$55.50 \ per \ year$$

According to this example, the average annual cost of forgoing the opportunity to invest the financial resources and gain a six percent annual interest return, instead of purchasing the screen filter, is $55.50 per year.

Taxes and Insurance Costs

Insurance costs depend upon coverage levels selected and can increase or decline over time based upon the type of coverage (replacement versus present value) and sales value of the asset. Property taxes and insurance costs can be approximated by multiplying the average annual investment times an annual tax and insurance rate. Taxes are typically calculated based upon an assessment rate that is multiplied by the full cash value to arrive at an assessed value. The assessed value is then multiplied times the tax rate per $1.00 assessed value. The annual tax rate to be applied to the average annual investment is therefore the assessment rate times the tax rate per $1.00 assessed value. The property that will be taxed, assessment procedures and tax rates, however, will all depend upon local tax provisions. The combined cost for annual taxes and insurance normally runs in the range of 1.5 to 2.5 percent of the initial value (purchase price) of the irrigation facilities.

Present Value

To carry out an annual cost calculation where individual items in the system are fully depreciated in less time than the period of analysis requires some means of accounting for component replacement. This is accomplished by determining the time at which the replacement would occur and then calculating the present value of the replacement that will occur at the beginning of the project. The present value is calculated by applying the interest rate being used for the analysis to the replacement cost of the item. The present value factor (PVF) and the present value (PV) are calculated by:

$$PVF = (1 + i)^{-n}$$

Equation 4.

$$PV = S \ x \ (1 + i)^{-n}$$

Equation 5.

where

S = replacement cost

i = interest rate

n = number of years in the future the replacement purchase will be made.

Example:

Determine the present value of a new self-priming centrifugal pump costing $1,152, to be replaced in two years. The current investment rate is eight percent.

Using Equation 4,

$$PVF = (1 + .08)^{2}$$

Using Equation 5,

$$\begin{aligned} PV &= \$1{,}152 \ x \ (1 + .08)^{-2} \\ &= \$1{,}152\,(.8573) = \$987.61 \end{aligned}$$

In this example, the cost of the pump is adjusted by a discount rate equal to eight percent interest compounded annually (PVF) and represents the amount of money that should be invested today to purchase the pump at a future date.

Amortization

The annual cost of capital invested in the irrigation system can be determined from the present value of the investment plus the interest incurred during the period of analysis. A commonly used approach for determining annual costs is to calculate a uniform series of annual values for depreciation and interest over the analysis period that is equivalent to the single present value. The value of this uniform series of annual costs is determined by application of an amortization factor, generally referred to as the capital recovery factor (CRF). This factor and the annual amortization value (AV) are calculated by:

$$CRF = i \ x \ (1 + i)^{n} \ x \ \left[(1 + i)^{n} - 1\right]^{-1}$$

Equation 6.

$$AV = PV \ x \ CRF$$

Equation 7.

Example:

Compare two alternative filters using an interest rate of eight percent. Filter 1 is an epoxy coated steel filter with an initial cost of $8,000 and an expected life of 10 years. Filter 2 is a stainless steel filter that has an initial cost of $12,000 and a life expectancy of 20 years.

Epoxy Coated Steel Filter:

Using Equation 5 and the Compound Interest Rate Table (Table 2),

$$PV = \$8{,}000 \ x \ (1.08)^{-10} = (\$8{,}000)(.4632) = \$3{,}705.60$$

Using Equation 6,

$$\begin{aligned} CRF &= .08 \ x \ (1 + .08)^{10} \ x \ \left[(1.08)^{10} - 1\right]^{-1} \\ &= .08(2.1589)(2.1589 - 1)^{-1} \\ &= .08(2.1589)(1.1589)^{-1} = (.08)(1.8629) = .1490 \end{aligned}$$

Using Equation 7,

$$AV = PV \ x \ CRF = \$3{,}705.60 \ x \ .1490 = \$522.13$$

Stainless Steel Filter:

Using Equation 5,

$$PV = \$12{,}000 \ x \ (1.08)^{-20} = (\$12{,}000)(.2145) = \$2{,}574$$

Using Equation 6,

$$CRF = .08\ x\ (1 + .08)^{20}\ x\ \left[(1 + .08)^{20} - 1\right]^{-1}$$
$$= .08(4.6610)(4.6610 - 1)^{-1}$$
$$= .08(4.6610)(3.6610)^{-1} = (.08)(1.2731) = .1019$$

Using Equation 7,

$$AV = PV\ x\ CRF = \$2{,}574\ x\ .1019 = \$262.29$$

In this example, the stainless steel filter required less than half the annual capital investment ($262.29) as the epoxy coated filter ($552.13) when amortized over the life of the filter.

Annual Operating Costs

The annual operation and maintenance (O&M) cost for an irrigation system includes the costs incurred for water, energy, lubrication, repairs, and labor. Improper design or operation of the system may increase overall O&M costs. Proper system design takes into consideration all of the economic factors when selecting each of the components of the system. A reduction in initial costs may result in an increase in the total annual per acre cost of the system. For example, removing labor saving features such as valves may increase labor costs enough to more than offset any savings earned by purchasing the lower cost equipment. Reduction in pipe sizes may increase fuel expenditures enough to more than offset equipment savings and may increase total annual cost. Therefore, it is highly important that the design engineer be thoroughly acquainted with all costs involved so that the system can be designed to operate most economically, thus contributing more to overall operation profits.

Annual Energy Costs

Annual costs for energy can be estimated by using observed average costs. Also, many engine manufacturers give average values for fuel consumption in terms of gallons or pounds of fuel per brake horsepower. Fuel consumption will vary depending on the condition of the engine and the manner in which it is maintained. The load imposed on the engine can be an important factor if it is operated at throttle settings beyond the manufacturer's recommendations, or if the system planner imposes an overloading condition on the engine. The annual energy costs will depend on the type of power unit used, cost of fuel or energy, and the overall efficiency of the pumping plant.

Except for electrical installations, power costs will vary directly with the horsepower delivered and the number of operating hours during the season. Internal combustion power use can be obtained from fuel consumption curves for the specific engine/pump combination used. If these curves are unavailable, average consumption data (per BHP-hour) rates can be used (Table 3). Power rates for electric motors can be obtained from local power utility supplies. Electric power schedules are frequently based on a fixed standby charge for the hp rating of the motor and a schedule of rates that decreases with the energy actually consumed. Off-peak use rates apply in some areas.

Fixed and Variable Costs

A distinction between fixed costs and variable costs is vital to any capital investment and production decision. Fixed costs are those costs which do not vary with changes in output. For example, the cost of a well pump assembly and power unit is the same whether the pump is operating or not. Fixed assets such as underground irrigation pipe or wells are fixed costs that are referred to as “sunk costs” because the expense is very difficult to recoup once it has been incurred. Variable costs are those costs which change with the level of output. Examples include fuel expense, labor, maintenance costs, and materials.

This distinction between fixed costs and variable costs is key to decisions revolving around the “produce or do not produce” question. In attempting to determine if output should be produced, in this case irrigation water, the level of fixed costs versus variable costs is paramount. If a grower decides it is not cost effective to irrigate a grove, only the variable costs should be considered because the fixed costs will be incurred regardless of the amount of water being pumped. If the economic benefits of irrigating are greater than or equal to average variable costs, then it is profitable to irrigate in the short run as the operation will incur a loss equal to its fixed costs only. In the long run, all costs are variable (because if given enough time, any factor of production can be changed). Therefore, in the long run, all costs, fixed and variable, must be covered in order to maximize profits or minimize losses.

Replacement Decisions

Many irrigation decisions involve the replacement of one or more system components. When a component is no longer repairable, the least cost replacement can be determined. However, often a component or system is operating at less than peak efficiency because of wear or obsolescence, but is still serviceable. The replacement decision can then be considered in the context of continuing for another year without replacement versus making the replacement. A projected years of use should be determined for the replacement that will result in minimum average annual cost. The minimum average annual cost can then be compared to the estimated cost of continuing with the existing system for another year. Replacement would be indicated if the average annual cost with replacement is less than the cost for the next year without replacement. This decision should also be considered each subsequent year if costs are to be minimized.

Where reduced efficiency of the system increases costs as well as reducing the amount of water that can be pumped, yield or quality of fruit may be reduced. Returns above variable costs should then be maximized rather than simply minimizing costs.

Example 1

Compare the minimum average annual cost of replacing a diesel engine with maintaining an existing power system. A new engine costs $25,000 and has a 20-year useful life expectancy. Annual tax and insurance expense totals two percent of the purchase price for both engines. The existing 18-year-old system costs $20,000 new and has a salvage value of $3,000. Annual maintenance and repair costs total $1,000 for the new engine and $3,000 for the existing engine. The existing system has fully depreciated. Current interest rates are eight percent.

NEW ENGINE:

Using Equation 6,

$$CRF = .08\ x\ (1 + .08)^{20}\ x\ \left[(1 + .08)^{20} - 1\right]^{-1} = .373\ x\ .273 = .1019$$

Using Equation 5,

$$PV = \$25{,}000\ x\ (1 + .08)^{0} = \$25{,}000$$

Using Equation 7,

$$AV = PV\ x\ CRF = \$2{,}547.15$$

Using Equation 1,

$$D_{avg} = \frac{\$25{,}000 - \$3{,}000}{20} = \$1{,}100$$

Using Equation 3,

$$AAI = \frac{\$25{,}000 + (\$25{,}000 + \$1{,}100)}{20} = \$2{,}555$$

Using Equation 2,

$$ACFI = \$2{,}555\ x\ .08 = \$204.40$$

Total Annual Expense Summary – New Engine

Amortization Value	$2,547.15
Maintenance	1,000.00
Tax and Insurance	500.00
Opportunity Cost of Investment	204.40
Total	$4,251.55

EXISTING ENGINE:

Using Equation 3,

$$AAI = \frac{\$20{,}000 + (\$3{,}000 + 0)}{18} = \$1{,}277.78$$

Using Equation 2,

$$ACFI = AAI\ x\ i = \$1{,}277.78\ x\ .08 = \$102.22$$

In Example 1, the total annual expenses of the existing engine ($3,502.22) are less than the total annual expenses of the new engine ($4,251.55).

Total Annual Expense Summary – Existing Engine

Maintenance	$3,000.00
Tax and Insurance	400.00
Opportunity Cost of Investment	102.22
Total	$3,502.22

Therefore, it is most economical to continue using the existing engine.

Example 2

The existing engine referenced in the previous example (Example 1) has reduced water volume to a 15-year-old 50-acre grove by 20 percent, from eleven inches to nine inches of water, reducing average grapefruit yield by twelve percent. Per-acre yield at eleven inches of water had averaged 450 boxes. The on-tree price per box is $1.96. Determine if the engine should be replaced.

Lost Production:
  Current average yield
    = 450 x .12
    = 54 boxes of lost fruit per acre
  54 boxes per acre lost x 50 acres
    = 2,700 boxes lost
  2,700 boxes lost x $1.96 per box
    = $5,292

Total Expense, New Engine: $4,251.55

Total Expense, Existing Engine:

Annual Expense	$3,502.22
Value of Lost Production	5,292.00
Total	$8,794.22

In Example 2, the value of lost production substantially increases the cost of the existing engine. Replacing the existing engine will reduce the real costs by one-half.

Table 1. Useful life and annual maintenance costs for microirrigation system components.

Component		Useful Life		Annual Maintenance Repairs
		(years)	*(hours)*	*(%)*
Pump House				0.5-.5
Reservoirs				1-2
Land Grading and Bed Formation				1-3
Well and Casing				0.5-1.5
Ditches (with annual maintenance)				1-2
Microirrigation System	Lateral tubing	8-12		1-3
	PVC pipe, underground	40		0.5-1
	PVC pipe, surface	10-15		1-3
	Aluminum components	10		1-3
	Valves	15		2-5
	Filters, coated steel	8		6-10
	Filters, galvanized	10		5-9
	Filters, stainless steel	15-25		4-8
	Emitter assemblies	5-10		5-8
Fertilization	Injection pump	3		4-8
	Solution tank	5		1-3
Electrical-Mechanical Components				5-10
Power Units	Diesel engine	14-22	28,000	5-8
	Electric motor	25-35	50,000-70,000	1-3
	Gasoline engine, air	8-12	8,000	6-9
	Gasoline engine, water	10-16	18,000	5-8
	Propane engine	14-22	28,000	4-7
Pumps	Centrifugal pump	15	32,000-50,000	3-5
	Vertical turbine pump bowls	8	16,000-20,000	5-7
	Turbine pump column	15	32,000-40,000	3-5
Power Transmission	Flat belt, fabric	6	10,000	5-7
	Flat belt, leather	8	20,000	5-7
	Flat belt, rubber	6-10	10,000	5-7
	Gear head	15	30,000	5-7
	V-Belt	4-8	6,000	5-7

Table 2. Compound interest (i) rate table.

	Interest (i) = 6%		***Interest (i) = 8%***		***Interest (i)* = 10%**	
	Future value of present sum	**Present value of future sum**	**Future value of present sum**	**Present value of future sum**	**Future value of present sum**	**Present value of future sum**
n	$(1 + i)^n$	$(1 + i)^{-n}$	$(1 + i)^n$	$(1 + i)^{-n}$	$(1 + i)^n$	$(1 + i)^{-n}$
1	1.0600	0.9434	1.080	0.9259	1.100	0.9091
2	1.1236	0.8900	1.166	0.8573	1.210	0.8264
3	1.1910	0.8396	1.260	0.7938	1.331	0.7513
4	1.2625	0.7921	1.360	0.7350	1.464	0.6830
5	1.3382	0.7473	1.469	0.6806	1.611	0.6209
6	1.4185	0.7050	1.587	0.6302	1.772	0.5645
7	1.5036	0.6651	1.714	0.5835	1.949	0.5132
8	1.5938	0.6274	1.851	0.5403	2.144	0.4665
9	1.6895	0.5919	1.999	0.5002	2.358	0.4241
10	1.7908	0.5584	2.159	0.4632	2.594	0.3855
11	1.8983	0.5268	2.332	0.4289	2.853	0.3505
12	2.0122	0.4970	2.518	0.3971	3.138	0.3186
13	2.1329	0.4688	2.720	0.3677	3.452	0.2897
14	2.2609	0.4423	2.937	0.3405	3.797	0.2633
15	2.3965	0.4173	3.172	0.3152	4.177	0.2394
16	2.5404	0.3936	3.426	0.2919	4.595	0.2176
17	2.6928	0.3714	3.700	0.2703	5.054	0.1978
18	2.8543	0.3503	3.996	0.2502	5.560	0.1799
19	3.0256	0.3305	4.316	0.2317	6.116	0.1635
20	3.2071	0.3118	4.661	0.2145	6.727	0.1486
21	3.3996	0.2942	5.034	0.1987	7.400	0.1351
22	3.6035	0.2775	5.437	0.1839	8.140	0.1228
23	3.8198	0.2618	5.871	0.1703	8.954	0.1117
24	4.0489	0.2470	6.341	0.1577	9.850	0.1015
25	4.2919	0.2330	6.848	0.1460	10.835	0.0923

Table 3. Average fuel consumption for internal combustion engines.

Engine Type	Fuel Consumption
Gasoline, air cooled	1/8 gallon/BHP-hour
Gasoline, water cooled	1/10 gallon/BHP-hour
Diesel	1/12 gallon/BHP-hour
Propane	1/7 gallon/BHP-hour