

ECONOMIC ANALYSIS

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INTRODUCTION

Investments in improved irrigation technology are necessary to manage a limited water supply with high efficiency. Irrigation systems with high distribution uniformities (DU) are necessary to achieve high irrigation efficiencies (IE) without incurring under-irrigation to parts of a field. High IE can be achieved by not refilling the root zone with an irrigation event, but eventually there will be parts of the field that will suffer water stress and yield reductions.

Generally the high DU irrigation systems include micro-irrigation and center pivot or linear move systems. In order to improve a furrow irrigation system to achieve a similar level of DU, significant capital investment is typically necessary to shorten the runs and install a tailwater reuse system. In limited situations border strip systems can achieve high DU.

Higher levels of investment can be justified by high value crops, such as trees and vines or truck crops, but there is only a limited, inelastic market for the crops produced and as such over production can reduce the value of these crops. Economic analysis is needed to justify the decision to invest in the equipment necessary to achieve high irrigation efficiency.

ANALYSIS TOOLS

This section will attempt to present the tools necessary to make a comparative analysis in a manner that is easily understood. Investment in improved irrigation systems is just one more annual cost that goes into growing a crop on a field. Most farmers must establish an annual budget to obtain financing from their bank, so we will look at the annual cost of an irrigation system.

The annual cost of an irrigation system will be determined from the initial cost of equipment, the cost of installation, finance charges, depreciation, water costs, energy costs, labor costs, maintenance costs, replacement costs (if particular components of the system have a life less than the time period of the analysis), and salvage value. Typically, to compare the cost of different possible irrigation systems, investments are resolved to a single "net present value" to allow an "apples to apples" comparison, particularly if the system life of the systems are not the same. The "net present value" of each system is then converted to an equivalent uniform series of equal annual costs, over the time period of the analysis. These equivalent annual costs are a fixed cost for the analysis of annual irrigation costs. This equivalent cost is combined with the other fixed and variable annual costs mentioned above to establish the annual cost of irrigation for a particular system, which is used to compare the potential profitability of alternate irrigation systems. Since depreciation costs are more of a tax question, we will not address that aspect of the cost, even though it can be a significant cost.

PAYMENT FACTORS

Factors will be presented to convert a single payment into a future value or a future value into the present value. Similar factors for

annual series of payments will also be discussed. Single payment factors are useful for analyzing the present value of purchasing replacement equipment in the future. Series payment factors are useful to take that present value (initial cost) and convert it to a uniform annual payment. There also exist factors for uniform gradient series, but they will not be considered here. Inflation adds another layer of complexity to economic analysis, and so we will assume that we are dealing with constant dollars, no inflation. For those that need to deal with inflation, there are engineering economics books available.

The uniform annual cost over an analysis period is obtained by using the Capital Recovery Factor of uniform annual series. This factor can be thought of as indicating the equivalent present cost (P) of equal annual expenditures (A) over N years at i percent interest and is designated A/P, where:

$$(1) \quad A/P = A/F \times F/P$$

And A/F is the Sinking Fund Factor, where:

$$(2) \quad A/F = [A/F, i, N] = i / ((1+i)^N - 1)$$

This factor is used to calculate the amount of annual investment (A) necessary to accumulate a future amount (F) when invested at i percent interest over a period of N years. And F/P is the Single Payment Compound-Amount Factor, where:

$$(3) \quad F/P = [F/P, i, N] = (1+i)^N$$

This factor is used to calculate the future amount (F) of a single present payment (P) that must be invested at i percent interest after N years. Please note that 1/(F/P) is the Single Payment Present-Worth Factor and is designated as P/F. P/F is the present amount (P) that must be invested at i percent interest to have a future amount (F) after N years.

These are standard financial factors and will be used in the remainder of this section. An engineering economic analysis [calculator](http://web.njit.edu/~wolf/calculator.html) (<http://web.njit.edu/~wolf/calculator.html>) page is available for these factors on the internet.

INTEREST RATE AND PAYMENT PERIOD

These financial factors are dependent on two variables, N, the investment period, and i, the interest rate. The interest rate can be known by several names, including the capital recovery rate and the discount rate and can be defined as the cost of having money available for use. In this economic analysis we will be using it to refer to the expected rate of return from an investment. The rate selected could be expected to be limited on the maximum side by expected the expected interest rate to borrow the funds and on the minimum side by the minimum rate that the water user expects from his own capital, over the period of analysis. On the maximum side, if the investor can get cheaper money than their own capital, they would be expected to use the other funds. On the minimum side, the investor can accept less for their own capital than they could readily earn from other investments, they would not make the investment in an improved irrigation system. A range might be between the bond market and expected loan rates.

Money has time value. By this we mean that a dollar received today has greater value than a dollar received in 5 years. A dollar now can be invested at a particular rate of return and would be worth more at the end of 5 years by the compound interest rate received from the investment, see equation 3 above. Similarly, you can calculate the present value that would need to be invested to return one dollar at the end of 5 years with the inverse of the same equation.

Alternative irrigation systems are investments that will support a particular rate of return from a farming operation. The system with the lower annual cost will provide the greatest profit, but the choice to invest in an irrigation system must be weighed against alternative investments. You can use economic analysis to determine if you can receive greater return in an alternative investment. A bank would look at a loan to finance your irrigation system as an investment.

It would seem reasonable that the interest rate selected for the economic analysis will be greater than other investments outside of farming with a similar level of risk. We have used a rate of 12 percent in the examples below, but that rate will also depend upon the length of the investment period. The choice of rate will also depend on whether you are doing an economic analysis or a financial analysis. An economic analysis is usually completed first and the financial analysis is completed to analyze the cash flow for the alternative selected. The same financial analysis factors can be used over a period that is related to the life of a loan.

The period of analysis for an economic analysis is not particularly sensitive to the length time chosen, but the most typical period is to chose it related to the useful life of the equipment involved. Equipment at the end of it's useful life will generally not have a salvage value, other than say the value of the aluminum itself from a portable irrigation system. Salvage value must be considered when the period chosen is shorter than the useful life, and this adds complexity. Typically on-farm irrigation systems would be analyzed over a period of 20 to 30 years. In order to work with longer times, replacement of equipment must be considered. The example below assumes an analysis period less that the useful life for illustrative purposes. The main criteria that must be

followed is that the period of analysis must be the same for all alternatives compared.

ANALYSIS EXAMPLES

We will first consider analyzing the cost of the irrigation equipment. Assume that you are considering the purchase of portable aluminum gated pipe to serve 160 acres. There is no installation cost for this type of system. Any installation would come as labor costs for putting it into the field when it was to be used. A system would be comprised of 66, 40 foot, joints of pipe to go across the top of the field, giving 2640 foot furrow runs. At \$180 per joint, the total cost of equipment is \$11,880. Assume a system life of 15 years, but that the analysis period of 10 years is used in this example. The analysis period could be the life of the equipment, the financing period or other appropriate period. The most important aspect is that any comparison is made alternatives with the same analysis period. The period length will determine if equipment replacement or salvage values should be considered. The interest rate selected should be appropriate for investment capital.

$$A = [A/P, 12\%, 10 \text{ years}] \times \$11,880.$$

$$A = [A/F, 12\%, 10 \text{ years}] \times [F/P, 12\%, 10 \text{ years}] \times \$11,880.$$

$$A = (.12/((1+.12)^{10} - 1)) \times (1 + .12)^{10} \times \$11,880.$$

$$A = 0.056984 \times 3.10585 \times \$11,880 = \$2,102.57$$

per year. or \$13.14/acre/year over 160 acres

This calculation can easily be performed on a simple financial or scientific calculator.

SALVAGE COST

The previous example assumes that there is no value for the pipe after 10 years. We need to calculate the uniform annual cost of the value of the equipment at the end of the planning period, the salvage value. Assume

that salvage value at 10 years is 33% of original cost.

Use equation (2) to calculate

$$A/F = (.12/((1+.12)^{10} - 1)) = 0.056984$$

to calculate the uniform annual series factor for the salvage value at 10 years. This is the annual cost that needs to be invested to accumulate the salvage value at 10 years. The annual cost of this system less the annual cost for the salvage value at the end of a ten-year period is,

$$A = \$2,102.57 - 0.056984 \times 0.33 \times \$11,880$$
$$A = \$2,102.57 - \$233.40$$

A = \$1,879.17 per year, or \$11.74/acre/year over 160 acres.

It should be noted that the actual market value of the equipment at the end of 10 years will probably be different than the salvage value used in the analysis. We will assume that the system is used only on one crop per year and that there are no energy costs, since the system is connected to the District distribution system. District deliveries are situated at the highest point of the field and have a minimum of 5 feet of head.

The annual irrigation system cost would be the annual system cost, \$1,879.17, plus the annual labor cost. The cost of the irrigation water will depend upon the crop grown. Therefore, in the previous example, the irrigation cost will be the cost of the system plus the cost of labor.

IMPROVED EFFICIENCY ALTERNATIVE

Thus, the irrigation cost will depend upon the efficiency, IE, of the system. An improved system with better DU can produce better IE

and reduce the amount of water applied and, therefore, the water cost. Reduced water costs can help pay for the improved system, but typically an improved system can also give improved yields, and reduce labor costs, which would help pay for the increased cost of the improved system.

Since we are in a limited water supply situation, it should also be noted that the water not applied to the field in question can be used to irrigate additional acreage. The additional profit from this additional acreage can also be used to justify the cost of the investment in improved technology.

IMPROVED IRRIGATION EFFICIENCY

Let's say that, in the interest of efficiency, you want to shorten the runs for the furrow irrigation system described above, but that the additional pipe would be purchased in increments, say 3 year periods to allow for the cash flow to improve. Assume that an additional 3/4 of a mile of pipe will be purchased to split the field into 1/4 mile runs 3 years subsequently and the remaining 7/12 of a mile (some of the gated pipe will be used for transport purposes) will be purchased 3 years later. The system will ultimately have 1/6 mile runs and could be used for a higher value crop like tomatoes. We will calculate the uniform annual cost over the same 10-year planning period and will assume the same unit cost for gated pipe.

The second investment will occur three years after the first. We will determine the present worth of the additional pipe and then use the capital-recovery factor to calculate the annual equivalent cost over the 10-year planning period. An additional 99, 40-foot, joints at \$180 are needed, at a cost of \$17,820. We will assume that the salvage value of the second purchase is 50% and the third

purchase will be 75% at the end of the 10-year period.

Calculating the present worth of the second purchase at 3 years we use the Single Payment Present-Worth factor, P/F, which is $1/(F/P)$, where F/P is equation 3 above:

$$P/F = 1/(F/P) = 1/[F/P, 12\%, 3] = 1/(1+i)^N = 1/(1+.12)^3 = 0.71178$$

< P > The present worth, P, of the purchase cost is $\$17,820 \times 0.71178 = \$12,683.20$. Using the uniform annual cost factors used above

$$[A/P, 12\%, 10] = 0.056984 \times 3.10585 = 0.17698$$

The annual cost for the second purchase is $0.17698 \times \$12,683.20 = \$2,244.80$ per year.

Assuming that the salvage value is 50% at 10 years, and the A/F value above, the annual cost for the salvage value is $0.056984 \times 0.50 \times \$12,683.20 = \$361.37$ per year.

The annual cost for the second purchase is $\$2,244.80 - \$361.37 = \$1,879.43$ or $\$11.75$ per acre per year.

Similarly for the third purchase of 77 joints after 6 years, the present worth factor, P/F, is

$$P/F = 1/(F/P) = 1/[F/P, 12\%, 6] = 1/(1+i)^N = 1/(1+.12)^6 = 0.50663,$$

with a net present value of $\$7,021.89$ and an annual cost of $\$1,242.73$. If the salvage value is 75%, then the annual cost is $\$300.10$. The annual cost for the third purchase is $\$1,242.73 - \$300.10 = \$942.63$ per year or $\$5.89$ per acre per year.

The uniform annual cost for the new improved system is now the sum of the individual annual costs,

$$\$1,879.17 + \$1,879.43 + \$942.63 = \$4,701.23$$

per year or $\$29.38$ per acre per year over the planning period of 10 years plus labor costs. This example assumes that the equipment would be sold at the end of the planning period, but demonstrates how to establish the annual cost of an irrigation system investment.

Typically, to achieve the highest DU a tailwater reuse system would be necessary. We will not develop the annual cost for this improvement because the configuration will be quite variable. A system that would integrate the tailwater management for several fields would amortize the cost over the largest acreage would probably have the minimum cost. A tailwater system will also be necessary to minimize the labor costs necessary to achieve the highest DU.

To justify the additional investment to improve the system efficiency, there must be at least an economic benefit of $\$17.71$ per acre. If you assume a water cost of $\$65$ per acre-foot, a reduction in the applied water of 3.3 inches, would be necessary to justify the improvement on water savings alone. If the original system was operating at 70% efficiency with a seasonal applied water of 30 inches, the improved system would need to be managed to achieve about 80% efficiency, with the same labor input, to justify the added investment by water cost reduction alone. The actual value of the water saved may not be the water cost, but it may be the value of the additional acreage that could be planted.

An investment in an improved irrigation system will typically be justified by one or more of the following factors that will

increase profits by reducing costs or increasing revenues:

1. Improved yield
2. Improved irrigation efficiency
3. Reduced labor costs