Chapter 11 Economic Evaluations

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Chapter 11 Economic Evaluations

652.1100 Forward

The material in chapter 11 is intended to be self help instructional material and reinforce formal training activities on the economics of irrigation. It is intended primarily to illustrate for field office personnel the use of economic principles and evaluation procedures. These principles and procedures should be helpful when working with land users analyzing the economics of irrigation. Additional help is available from technical specialists. For an expanded discussion of economic evaluations, see The Handbook of Economics for Conservation, Natural Resources Conservation Service (NRCS), April 1992, and Farm Management Course Notebook, NRCS and America Society of Farm Managers and Appraisers, 1994.

652.1101 General

Decisions are made daily whether to purchase an item or which item to purchase. Economics is the process of deciding where and how we spend our money ranging from pennies to thousands of dollars. Therefore, what factors do we analyze in deciding how to spend our money? Normally we compare the benefits of the purchase or investment to its cost. Someone considering the purchase of a new car might see better gas mileage and fewer repairs as benefits. Costs might include higher car payments and higher insurance premiums. Someone wanting a new computer might be comparing benefits that a new computer would give them in business and at home to the cost of giving up other activities or items currently enjoyed.

Farmers, when deciding whether to purchase an irrigation system, go through much the same thought process. They may ask, “Should I continue my dryland farming operation or should I irrigate? If I decide to irrigate, how much water should be applied to get the greatest profit? Will the greatest profit be realized at the point of maximum yield? Will the increase in yield more than pay the increase in costs?”

These questions can be asked when contemplating whether to replace an existing irrigation system. What are the proposed changes? What are the costs? What are the benefits? Is there a better alternative? For example:

- Improved water management with the existing irrigation system, or
- Improved precipitation storage in the soil resulting from improved soil condition, better crop residue use, changed (usually reduced) number and type of tillage operations, performing farming operations on the contour, or
- A combination of 1 and 2.

The need for change should be based on using the existing irrigation system along with proper water, soil, and plant management. Too often a poorly managed surface irrigation system is compared to a properly managed sprinkler or micro irrigation system. Assumed level of management can be guided by observing the irrigation decisionmakers current irrigation water management and other farm management practices. If the water user is an average surface irrigation system manager, chances are he/she will be an average sprinkler or micro irrigation system manager. Automated systems typically require higher levels of management.

Existing irrigation systems should be checked for both management and system operational efficiencies. The basis for change should include an economic evaluation of annual costs and benefits. Included are annual operating cost, labor availability and cost, annual cost of installing the existing irrigation system, and annual net income using the existing irrigation system.

The decision to purchase an irrigation system is often based on an inadequate economic analysis. Data are usually available or can be easily obtained to answer questions in paragraph two of this section. The management ability and performance of the operator are probably the most important factors in determining the feasibility of irrigation or making a change in an existing irrigation system. Good water management is essential to realize the full benefit of irrigation. Under poor management a farmer will be paying the full cost of irrigation, but realizing only part of the benefit.

A perception among many irrigators is that to do a better job irrigating, a different irrigation method or system must be used; i.e., convert from surface irrigation method to the sprinkle method. Often, however, greater benefits can be derived with improved water management (includes irrigation scheduling and system maintenance using the existing irrigation system). All irrigation methods (surface, sprinkle, micro, and subsurface) can distribute an amount of water uniformly across a field. However, site conditions for some irrigation systems can be quite limiting and labor requirements high. **The first increment of change should always be to optimize the use of precipitation and irrigation water applied using the existing irrigation system (if one exists).**

Each NRCS employee should be aware of the economics of irrigating in the general area and be familiar with the procedure used in analyzing data to determine feasibility.

This chapter provides tools necessary to evaluate the feasibility of installing an irrigation system. These tools, or principles, can also be used to evaluate other types of conservation investments.

652.1102 Economics of installing a new irrigation system

An Economic Analysis consists of a Benefit Analysis, Cost Analysis, and a Benefit-to-Cost Analysis. A Marginal Cost - Marginal Return Analysis can be made to show the relationship per increment of change. For example, per bushel of yield return or per inch of water applied. Each of these components will be described in this chapter.

(a) Benefit analysis

Before installing an irrigation system, a *benefit analysis* should be completed to determine management requirements and profitability of such an investment. An irrigation system should be recommended only if it:

- Improves the net income of the operator.
- Reduces or favorably changes the amount, timing, or type of labor required.
- Has positive benefits on soil, water, air, plant and animal resources.

Since there are four irrigation methods and many different irrigation systems to apply water by these methods, the decision becomes extremely critical in selecting an irrigation method and system that will maximize profits while protecting the environment. To help make this determination, the water user or consultant should **employ economic tools as a part of the planning process to provide best management and system alternatives for a given water user's situation.**

The beneficial evaluation of an irrigation system is usually based on the premise that production, crop quality, or both, will increase as a result of making irrigation management and system changes. This assumption is made with the knowledge that physical, chemical, and biological properties of the soil, or seasonal variation of temperature and the timing and availability of irrigation water are not a hindrance to increased production or quality potential.

Gross benefits from an irrigation system are fairly easy to identify as compared to benefits from a grassed waterway or terrace system. Sufficient data have been obtained, either by research or actual field conditions, to develop a reliable relationship between available water and yield. In reality, benefits, in addition to increased yields, will probably be included in the evaluation. These benefits can involve higher unit prices for improved quality, reduced cost of operation per unit of product produced, and with improved water management reduced water use per unit of product produced. Average yields rather than maximum yields are recommended for cost benefit analysis. Maximum yields do not reflect negative impacts from weeds, insects, wildlife, or cool growing seasons that can occur.

The site selected for the following example has an average annual effective rainfall of 19.3 inches, of which 10 inches is considered available (effective) for plant use most years. Average dryland corn yield on the example farm is 40 bushels per acre. Well managed neighboring farms, also on deep silt loam soils, apply 16 inches of irrigation water to get an average of 170 bushel per acre yield. Supporting data in section I of the FOTG support these numbers. In the example one alternative will be evaluated, while in reality, several alternatives would most likely be evaluated. Alternative systems could consist of different irrigation methods, different irrigation systems, automated versus manual system operation, costs, and benefits.

The example alternative to be evaluated is a proposed 130-acre center pivot sprinkler irrigation system to supplement natural precipitation (dryland farming). At 75 percent irrigation application efficiency, about 12.5 inches of the 16.7 inches applied plus 10 inches of growing season precipitation is available for plant use. Crop budgets show that the increase in gross return will be $347.10 per acre, rounded to $347. This is calculated from the 130 bushel yield increase at a price of $2.67 per bushel.

In summary, it can be said that the average annual benefits, excluding the cost and operation of the irrigation system and the increased variable production costs of corn, is $347 per acre per year. Exhibit 11–1 may be helpful in determining gross benefits.

Exhibit 11–1 Gross benefits worksheet (using example 130-acre site)

U.S. Department of Agriculture
Natural Resources Conservation Service

Gross Benefits Worksheet

Crop ___Corn___ Date [1/] ________ Year of price base [2/] ________

Existing irrigation system ___none___ Planned irrigation system ___center pivot sprinkler___

Gross value per acre of expected increase from irrigation:

___130 bu/ac___ yield increase x ___$2.67___ per unit (i.e. bu, etc.) = ___$347.10___ (rounded to ___$347___)

1/ Date—For future reference, it is helpful to show the date the estimates were made.
2/ Year of price base—The price base is normally the current year prices.

(b) Cost analysis

The next step in an economic analysis is a *cost analysis*. The average annual cost per acre to own and operate the irrigation system and the increased annual production costs must be determined so that the benefits and costs can be compared.

One of the most difficult tasks in performing a cost analysis is to include all costs. Costs associated with any enterprise can be diverse and thereby easily overlooked. For this reason farm decisionmakers should try to follow guidelines such as those in this chapter. Farm decisionmakers and economists categorize costs as fixed and variable to assist in both long-term and short-term financial decisions. These two categories together constitute total costs.

Costs are generally classified as being either ownership costs (fixed costs) or operating costs (variable costs). Ownership costs are those costs incurred even if no production takes place. These costs are also independent of changes in yield. Examples of ownership costs are depreciation, insurance, taxes, interest, housing, and some maintenance. These costs must be paid each year the equipment is owned, even if the equipment sits idle. Actual loan amortization is an annual ownership cost consideration, typically shorter than the life of purchased equipment.

Operating costs, commonly called variable costs, are those costs that occur as production takes place. Typical operating costs are seed, fuel, fertilizer, power for irrigation systems, and labor. If production does not take place, operating cost items are not needed.

The decision to purchase, rent, or lease irrigation equipment is extremely important. Fixed cost, variable costs, and total cost should all receive some attention. Once the purchase has been made, however, the decision to use it in any given year is linked closely to variable costs.

(1) Ownership (fixed) costs

The estimated cost of the proposed 130 acre center pivot irrigation system is shown in exhibit 11–2.

Exhibit 11–2 Ownership (or fixed) costs (using example 130-acre site)

Ownership Costs

Center pivot sprinkler system installed with concrete pad at pivot, system completely set up	$ 41,000
Well, 400 feet of steel well casing, installed with gravel pack, located at pivot	14,000
Installed pump (head, bowls and column) with yield of 1,000 gal/min at 80 lb/in^2	13,000
Electric motor (125 hp range) installed	5,500
Install 0.25-mile underground electric wire, control panel at pump	14,000
Subtotal	$ 87,500 for 130 ac = $673/ac
Contingencies at 10 percent	8,750
Subtotal	96,250
Sales Tax at 4 percent [1/]	3,850
Total estimated cost of irrigation system	$ 100,100
(Rounded for capital investment analysis)	$100,000 for 130 ac = $769/ac

1/ This is a conservative number. Items that require payment of sales tax vary by state.

The $100,000 installation cost must now be converted to an average annual cost. This conversion is necessary so that both the benefits and costs are expressed in comparable terms, that is, average annual dollars. Exhibit 11–3 can help determine the average annual ownership costs per acre.

Note: The following information is helpful in using the worksheet:

Date—For future reference, it is helpful to show the date the estimates were made.

Year of price base—The price base will normally be the current year prices.

Equipment or irrigation system—Identify the equipment or irrigation system represented in the analysis. In this case a center pivot sprinkler irrigation system.

Life span—The number of years the equipment or irrigation system is expected to be used in an operation or business. It may be the age at which time the item is completely worn out, or the period may be shorter if the equipment is expected to be sold or replaced while retaining some of its original value. Life span for individual components varies. See table 5–2, Chapter 5, Selecting an Irrigation Method.

Maintenance costs usually increase with age and use of the equipment. The cost of maintenance may also be used to determine the useful life of equipment. **When annual maintenance cost exceeds the annual cost of purchasing new equipment, then the economic life has been exceeded.** The farm manager may still use it if a major investment cannot possibly be afforded at this time, or the manager has become personally attached to a specific piece of equipment; i.e., an old tractor that still functions satisfactorily.

If the purchase was made with borrowed funds, the owner for cash flow purposes may also want to make an analysis using the years of loan repayment as the year life, even though the equipment may physically last longer. In this example all irrigation equipment has been assigned a 15-year life. (A more detailed economic evaluation would assign different life expectancies to each major system component. A separate analysis would be completed for each component.)

Acres annual use—The number of acres the equipment will be used annually. In this example, the center pivot will be used on 130 acres; 30 acres in field corners will remain dryland.

Interest rate—Use either (a) actual loan rate if funds are borrowed, or (b) a representative, competitive market rate or opportunity cost if producer provides funds (not borrowed).

New cost—The purchase price plus installation cost. For this example the initial cost is $100,000.

Salvage value—This is usually the salvage value or remaining value at the time of replacement. This value may be zero if it is completely worn out and has no scrap value or will never be sold. Equipment that is expected to be replaced after a given period of time and with some remaining operational use should be assigned a trade-in value. The system in this example is expected to have a remaining value of $5,000, 15 years hence.

The annual value or cost of the salvage value will be the present value times an interest rate represented by the opportunity cost or the cost of borrowed money. If one's own money is used to purchase the equipment, use the opportunity cost. This would be the interest rate one could get by investing the money in alternative investments having similar risk and time frames. If funds are borrowed, use the interest rate being charged for the use of those funds. In this example, 12 percent has been selected. The $5,000 salvage value is discounted to present value (see table 11–1 for present value factors) and then amortized over the 15-year period. The $5,000 represents the value of the equipment 15 years hence, or at the end of 15 years.

$5000 x Present value of 1, 15 years hence
@ 12% (0.18270) = $914

Amortization—Amortization involves prorating the initial cost, less salvage value of equipment over its useful life, in this case $99,086 over a 15-year period. See table 11–2 for amortization factors. The value of equipment decreases each year through wear, deterioration, or obsolescence, and that value should correspond to the amount of amortization taken each year. The net investment is converted to an average annual cost by amortization. Amortization, also called capital recovery, is the extinguishing of a financial obligation in equal installments over time.

Amortization, as used in this example, will convert the net capital (investment) cost into an annual cost, which also includes the interest or opportunity cost. Using an interest rate of 12 percent and a life of 15 years, find the appropriate amortization factor (0.14682) from table 11–2 or an average annual cost table. The present value of a salvage value 15 years hence (in this example, $5,000 x 0.18270 = $914) is subtracted from the investment cost (in this example, $100,000 – $914 = $99,086). The factor 0.14682 times $99,086 = $14,548. The $14,548 is the average annual cost of ownership associated with the amortization of the irrigation equipment over the life span of the equipment.

Table 11–1 Present value factors for single payment

Borrowing interest (%)	Cost factors at various expected years of loan							
	6 yr	8 yr	10 yr	12 yr	15 yr	18 yr	20 yr	25 yr
7.0	.66634	.58201	.50835	.44401	.36245	.29586	.25842	.18425
8.0	.63017	.54027	.46319	.39711	.31524	.25025	.21455	.14602
9.0	.59627	.50187	.42241	.35553	.27454	.21199	.17843	.11597
10.0	.56447	.46651	.38554	.31863	.23939	.17986	.14864	.09230
11.0	.53464	.43393	.35218	.28584	.20900	.15282	.12403	.07361
12.0	.50663	.40388	.32197	.25668	.18270	.13004	.10367	.05882
13.0	.48032	.37616	.29459	.23071	.15989	.11081	.08678	.04710
14.0	.45559	.35056	.26974	.20756	.14010	.09456	.07276	.03779
15.0	.43233	.32690	.24718	.18691	.12289	.08081	.06110	.02038

Table 11–2 Cost factors (amortization)

Borrowing interest (%)	Cost factors at various expected years of loan							
	6 yr	8 yr	10 yr	12 yr	15 yr	18 yr	20 yr	25 yr
7.0	.20980	.16747	.14238	.12590	.10978	.09941	.09439	.08581
8.0	.21632	.17401	.14903	.13270	.11683	.10670	.10185	.09368
9.0	.22292	.18067	.15582	.13965	.12406	.11421	.10955	.10181
10.0	.22961	.18744	.16275	.14676	.13147	.12193	.11746	.11017
11.0	.23638	.19432	.16980	.15403	.13907	.12984	.12558	.11874
12.0	.24323	.20130	.17698	.16144	.14682	.13794	.13388	.12750
13.0	.25015	.20839	.18429	.16899	.15474	.14620	.14235	.13643
14.0	.25716	.21557	.19171	.17667	.16281	.15462	.15099	.14550
15.0	.26424	.22285	.19925	.18448	.17102	.16319	.15976	.15470

Interest costs—When capitol is borrowed to make the initial purchase, interest cost is a fixed cost. However, unlike amortization, interest or opportunity cost varies with the size of the initial obligation without consideration of salvage value. Purchasing irrigation equipment ties up capital (money); therefore, it has an opportunity cost. This opportunity cost is the interest cost. If a farmer purchases a sprinkler irrigation system for a farm and finances through the owner or bank on a contract, he/she agrees to repay the principal amount in a certain number of years. In addition to the repayment of the principal, the borrower must also pay an interest charge each year. Borrowed capitol is often repaid in a time period less than the life span of equipment and materials purchased. Farm decision-makers can choose to use this shorter time period to amortize the initial investment, recognizing salvage value at the end of the amortized period could be substantial. However, money is still tied up in the irrigation equipment, and opportunity cost (interest) still applies.

Taxes—Some states levee a property tax on equipment or farm machinery. In this example taxes were assumed to be $2,000 per year.

Insurance—This is an annual charge to cover the loss of equipment from fire, theft, windstorm, or any liability coverage. It is estimated to be $2,000 per year in this example.

Standby (fixed) charges for electricity—Providing electrical power availability is generally passed on as a fixed cost. Standby charges are paid even if the irrigation system is not used. In this example the standby charge was $24.84 per acre or $3,230 per year. These charges set by the electric utility company are payable every year. In some areas standby charges are called demand charges.

Ownership cost per year—This is the sum of the annual ownership costs of the irrigation system. In this example it is $21,278.

Ownership cost per acre—This is the total annual ownership cost prorated over the number of acres the system is benefiting. In this example the system is benefiting 130 acres, so the annual ownership cost is $21,278 divided by 130 acres, or $168 per acre.

Most of the ownership costs have now been accounted for and determined to be $168 per acre per year. Total annual costs consist of ownership (fixed) costs and operating (variable) costs. With the total annual costs known, it can be compared to the total annual benefits. Notice the break even cost is now $168 per acre greater than before the irrigation system was installed. This difference can only be recovered by increased outputs (plant yield or biomass) or reduced inputs (labor, tillage).

Exhibit 11–3 Increased ownership cost worksheet (see text for explanation of terms)

U.S. Department of Agriculture
Natural Resources Conservation Service

Increased Ownership Cost Worksheet

Crop *Corn* Date 1/ ______ Year of price base 2/ ______

Equipment or irrigation system *Center pivot sprinkler irrigation system*

Life span *15 years*, Acres annual use *130 ac*, Interest rate *12%*

Ownership Costs

New cost		$100,000	
Salvage value		5,000	
Present value	$5,000 at 12% for 15 years		
	$5,000 x (.18270)	914	
Net investment	$100,000 – 914	99,086	
Amortization	$ 99,086 @ 12% for 15 years		
	$ 99,086 x (.14682)		$ 14,548
Taxes			2,000
Insurance			2,000
Standby (fixed) charges for electricity			3,230
Ownership cost per year			$ 21,778

Increased ownership (fixed) cost per acre

$$\frac{\$21{,}778}{130} = \$167.52$$

$$= \$168 \text{ per acre}$$

1/ Date—For future reference, it is helpful to show the date the estimates were made.
2/ Year of price base—The price base is normally the current year prices.

(2) Operating (variable) costs

In the example, operating costs of the center pivot sprinkler irrigation system and the increased corn production costs are estimated in exhibit 11–4. The format in this exhibit can help develop these costs.

Exhibit 11–4 Increased operating costs worksheet

U.S. Department of Agriculture
Natural Resources Conservation Service

Increased Operating Cost Worksheet

Crop *Corn* Date 1/ ______ Year of price base 2/ ______

Irrigation system equipment *Center Pivot Sprinkle Irrigation System*

Increased yield per acre (bu, ton, bale, etc.) *130 bu*

Increased operating costs	Increased cost per acre	Increased cost per bushel
Electric power for *16* acre inches of water applied per acre at *$4.50* per acre-inch 3/	$ 72	$ 0.55
Repair and maintenance of irrigation system: *$1,560* a year divided by *130* acres benefiting 3/	12	0.09
Increased costs of fuel, oil, seed, fertilizer, harvest, interest, chemicals, labor, water required to obtain the *130* bushel increase in yield 3/	66	0.51
Total increased operating costs per acre 4/	$ 150	$ 1.15

1/ Date—For future reference, it is helpful to show the date the estimates were made.
2/ Year of price base—The price base is normally the current year prices.
3/ Field Office Technical Guide, Section I.
4/ This figure is used in table 11–2, section 652.1104.

(c) Benefit-to-cost analysis

Basic data for a benefit-to-cost analysis has now been completed. Benefits and increased ownership and operating costs are on an average annual per acre basis and can be analyzed to determine system feasibility. Exhibit 11–5 can help put these items in perspective.

Observation: From the example benefit-to-cost analysis, we can conclude that the irrigation system is a good investment. The system will pay its own way and produce an additional $29 annual income per acre. The break-even point can also be calculated. We know that the average annual increase in costs associated with the irrigation system is $318 ($168 + $150) per acre. At a price of $2.67 per bushel, it would take a 119 bushel ($318 divided by $2.67) per acre increase in yield, or a total yield of 159 bushels to break even. Break-even price for 170 bushel yield would be:

$$\frac{\$318}{(170-40)\text{ bu}} = \$2.45 \text{ per bu}$$

Exhibit 11–5 Feasibility worksheet

U.S. Department of Agriculture
Natural Resources Conservation Service

Feasibility Worksheet

Crop *Corn* Date [1/] ______ Year of price base [2/] ______

Irrigation system equipment *Center Pivot Sprinkle Irrigation System*

Increased yield per acre (bu, ton, bale, etc.) *130 bu*

	Costs	Benefits
Gross value per acre of expected increase (from exhibit 11–1)		$ 347
Average annual ownership cost per acre of irrigation system (from exhibit 11–3)	$ 168	
Average annual operating cost increase per acre (from exhibit 11–4)	150	
Total average annual cost increase per acre	$ 318	318
Expected average annual increase in net income per acre		$ 29

1/ Date—For future reference, it is helpful to show the date the estimates were made.
2/ Year of price base—The price base is normally the current year prices.

The procedure used in this analysis illustrates steps that can be used to evaluate similar investments. Regardless of the system being evaluated, general procedures and principles remain the same:

1. Using crop budgets, identify and calculate annual gross benefits resulting from the change.
2. Identify and calculate increased costs on an annual basis.
3. Compare annual benefits to annual costs for feasibility.

Decisions made from these calculations are extremely important, and the magnitude of ownership (fixed) and operating (variable) costs in relation to the benefits is the deciding factor. They can also affect the decision to purchase, rent, or lease equipment.

Partial budgeting can be used when calculating and comparing several alternatives. With partial budgeting, only costs that change with each alternative are considered. Crop budgets prepared by university farm commodity and other specialists should always be considered.

652.1103 Economics of operating an existing system

Once an irrigation system has been purchased, the decision to use it in any given year is linked closely to the variable costs. This section shows why this is true and illustrates a procedure that can be used in the analysis.

(a) Benefit analysis

The process to determine the benefits of continuing to use an existing irrigation system is the same as that used for the analysis of a new system. The same format may also be used (exhibit 11–6).

Summary: In this example, it can be said that if irrigation takes place and anticipated benefits do occur, estimated gross benefits will be $347 per acre. Costs incurred to obtain these gross benefits need to be determined.

Exhibit 11–6 Gross benefits worksheet

U.S. Department of Agriculture
Natural Resources Conservation Service

Gross Benefits Worksheet

Crop Corn Date 1/ ______ Year of price base 2/ ______

Gross value per acre of expected increase from irrigating the crop:

130 bu/ac yield increase x $ 2.67 per unit (bu, lb, ton, bale, etc.) = $ 347.10

rounded to $347 per acre.

1/ Date—For future reference, it is helpful to show the date the estimates were made.
2/ Year of price base—The price base is normally the current year prices.

(b) Operating costs

Since the system is already installed and the ownership costs ($164 per acre per year) are obligated, the decision to irrigate or not depends on the anticipated increase in income being greater than the cost of operating the system (pumping costs, repairs) plus increased costs of production (seed, fertilizer, chemicals, labor). Exhibit 11–7 may be helpful in calculating these costs.

Exhibit 11–7 Increased operating costs worksheet

U.S. Department of Agriculture
Natural Resources Conservation Service

Increased Operating (Variable) Cost Worksheet

Crop *Corn* Date [1] ______ Year of price base [2] ______

Irrigation system equipment *Center Pivot Sprinkle Irrigation System*

Operating costs of item:	Increased cost per acre
Electric power, *16* acre inches of water applied at *$4.50* per acre inch	$ 72
Repair and maintenance of irrigation system: *$1,560* a year divided *130* acres benefiting	12
Increased costs of fuel, oil, seed, fertilizer, harvest chemicals, labor, water, etc. required to obtain the *130* bu/ac (bu, ton, bale, etc.) increase in yield	66
Increased operating (variable) costs per acre	$ 150

1/ Date—For future reference, it is helpful to show the date the estimates were made.
2/ Year of price base—The price base is normally the current year prices.

(c) Benefit-to-cost analysis

Irrigation should take place if additional income from the increased yield resulting from irrigating is greater than increased production costs plus the cost of operating the system. This is especially true in the short term even if additional income does not completely cover ownership costs (principle, taxes, insurance, interest). These costs will occur even when the system is setting idle. In the long term, other considerations may need to be made. Example 11–8 illustrates why one would irrigate as long as operating costs are covered. In reality, operating cost per acre will usually increase with increased yield to additional water, fertilizer weed control, and harvest costs.

Summary: Exhibit 11–8 shows that if the additional income will not cover the additional operating cost, it is economically feasible to leave the system idle. Once operating costs are covered, it is probably best to run the irrigation system and partly or completely recover ownership costs. Profits will be realized when additional income exceeds the sum of ownership and operating costs. Being aware of a close profit margin can stimulate farm decisionmakers to look at other areas where costs can be reduced; i.e., reduced tillage, proper irrigation scheduling, soil management practices to capture a greater portion of rainfall during the growing season. In this example, operating costs were kept constant. In reality, the cost of producing additional yield can increase, such as using additional seed and applying more fertilizer and water. Improved water management can also increase.

Exhibit 11–8 Benefit-to-cost analysis

Increased ownership cost $/ac	Increased operating cost $/ac	Additional yield/income bu/ac	Additional yield/income $/ac	Net gain or loss $/ac	Notes
168	None	0	0	–168	System is idle, lose only the ownership costs.
168	150	25	7	–251	Ownership and operating costs not covered, better off left as dryland.
168	150	50	133	–185	Covered operating costs and some ownership costs. Probable better left as dryland.
168	150	75	200	–118	Covered operating costs and some ownership cost. Lose $118/ac.
168	150	100	267	–51	Covered operating costs and most ownership costs. Lose only $51/ac.
168	150	119	318	0	Break even, ownership, and operating costs covered.
168	150	125	334	+16	Gain $16/ac.
168	150	150	400	+82	Gain $82/ac.

652.1104 Maximizing net returns

If profits are to be maximized, existing irrigation systems must be checked for operational efficiency and proper management. The management ability and desire of the operator are probably the most important factors in determining the feasibility of irrigation. Good water management is essential to realize the full benefit of irrigation. Under poor management a farmer will be paying the full cost of irrigation, but realizing only a portion of the benefits. Too often yields are reduced with poor water management (improper amount, timing, or both). A good manager seeks out answers to questions, such as *How much water should be applied to realize the greatest profit? Will the greatest profit be realized at the point of maximum yield? Will the increase in yield pay more than the expense of irrigation?* The following procedure can help answer these questions.

(a) Marginal cost and marginal return

The previous analysis in this chapter has been concerned with the feasibility of investment in an irrigation system. The question analyzed was: *Should I switch from a dry cropland system to an irrigation cropland system of crop production?*

Once the question has been analyzed and answered and the irrigation system installed, the optimal amount of irrigation water to apply needs to be considered. The optimal amount of water to apply is where the marginal cost is equal to the marginal return for applying an additional 1.0 acre-inch per acre of water.

It is easiest to think in terms of increments. Each 1.0 acre-inch per acre of water applied will produce an associated increment of costs and an associated increment of dollar return. In the relevant range of production, the incremental cost will increase while the incremental return will decrease. Production should occur where the two increments are equal.

Ownership costs of existing systems are unimportant. The per increment cost (marginal cost) and what that increment produces (marginal return) are important. Increments can be per acre-inch of water applied, per pound of fertilizer applied, or per pesticide application.

The marginal cost in this example is the additional cost of irrigation incurred when an additional acre-inch of water is applied. Marginal return is the additional net return resulting from the added acre-inch of water. Profits are maximized when the marginal cost is equal to the marginal return. In the example, the variable input, water, should be added in increments until the cost of adding the last increment (in this case an acre-inch of water) is equal to the net return resulting from the addition of the increment.

(b) Water-yield relationships

Required in any marginal cost to marginal return economic analysis, and to continue the example analysis, is the physical output resulting from the various increments (acre-inches of irrigation water) applied. Table 11–3 shows a water-yield relationship.

Table 11–3 Developing water use-yield relationship

- - - - Total water - - - - applied 1/ (in)	deficit 2/ (in)	Reduction in ET 3/ (%)	Reduction in yield 4/ (%)	- - - - - - - - Corn - - - - - - - - - loss 5/ (bu)	yield 6/ (bu)	- - Water applied - - net 7/ (in)	gross 8/ (in)	Marginal yield 9/ (bu/ac-in)
10	16	61.5	76.9	130.8	40.0	0	0	
11	15	57.7	72.1	122.6	47.4	1	1.3	7.4
12	14	53.8	67.3	114.4	55.6	2	2.6	8.2
13	13	50.0	62.5	106.2	63.8	3	4.0	8.2
14	12	46.2	57.8	98.1	71.9	4	5.3	8.1
15	11	42.3	52.9	89.9	80.1	5	6.6	8.2
16	10	38.5	48.1	81.7	88.3	6	8.0	8.2
17	9	34.6	43.3	73.6	96.4	7	9.3	8.1
18	8	30.8	38.5	65.4	104.6	8	10.6	8.2
19	7	26.9	33.7	57.2	112.8	9	12.0	8.2
20	6	23.7	28.8	49.0	121.0	10	13.3	8.2
21	5	19.2	24.0	40.9	129.1	11	14.6	8.1
22	4	15.4	19.2	32.7	137.3	12	16.0	8.2
23	3	11.5	14.4	24.5	145.5	13	17.3	8.2
24	2	7.7	9.6	16.3	153.7	14	18.6	8.2
25	1	3.8	4.8	8.2	161.8	15	20.0	8.1
26	0	0	0	0	170.0	16	21.3	8.2
27	0	2	2.5 10/	4.3	165.7	17	22.7	–4.3
28	0	4	5.0	8.5	161.5	18	24.0	–8.5
29	0	6	7.5	12.7	157.2	19	25.3	–12.8
30	0	8	10.0	17.0	153.0	20	26.7	–17.0

1/ Normal rainfall at this site is 19.3 inches. Approximately 10 inches is considered available for plant use most years. 1-inch increments are added to this base.
2/ The annual potential evapotranspiration (ET) value for this crop, at this location, is 26 inches net. This column lists the average annual shortage.
3/ ET deficit divided by 26 inches net ET requirement x 100 = percentage reduction in ET. Reduction in yield because of overapplication of water based on limited research and field observation. Actual yield reduction depends on climate, soils, residual soil moisture, and cropping history.
4/ Percent reduction x 1.25. From Food and Agricultural Organization Irrigation and Drainage Paper No. 33—Yield Response to Water or Analysis of Land Treatment Practices for Water Conservation, published in the proceedings of the National Workshop on Planning and Management of Water Conservation Systems in the Great Plains States, October 21-25, 1985, Midwest National Technical Center, Natural Resources Conservation Service, Lincoln, NE.
5/ Percent reduction in yield x 170 (170 is assumed to be the average potential yield in this area).
6/ Maximum yield – loss in bushels. Use actual yield (i.e., 40 bu) if available and adjust subsequent values. In this example, assumed yield increase versus water applied function is approximately 8 bu/ac for each 1 ac-in water applied, with a maximum yield of 170 bu/ac.
7/ Net acre inches of irrigation water supplied at 75 percent irrigation application efficiency.
8/ Gross acre-inches of irrigation water applied.
9/ Marginal occurs at approximately half the rate as does a corresponding moisture deficit. For this reason, growers often schedule irrigations on the wet side of optimum. There is about half the risk of adversely affecting yields.
10/ On the average, a reduction in yield occurs as additional water is applied.

(c) Production function

Once the yield data (output) are developed for each increment of the variable input (water), a total production curve can be developed. Product yield versus water applied for the example farm is plotted as figure 11–1. From this production curve we can also develop the relationship between the marginal cost and marginal return to determine at what level of water application the profits will be maximized (table 11–4).

The first example demonstrated the gross decision process for whether to irrigate. Also important is an incremental decision regarding what is the economic effect per increment of input. In this case once irrigation is chosen, a decision must be made on how much water is applied. The information in table 11–4 is based on:

> Corn @ $2.67 per bushel – $150 per acre ÷ 130 bushel per acre (variable or increased cost per total increased yield) = $1.15. (From exhibit 11–4, $150 per acre is the increased variable cost to produce 130 bushels per acre of corn.) Net income for the 130 bu/ac increase = $2.67 – $1.15. Marginal cost - marginal return analysis is an analysis of affects created by adding increments of input—in this example, 1 acre-inch per acre of water. It is a separate process, and not a part of other cost to benefit analysis.

From table 11–4, we see that each time 1 net inch of water is applied, the cost is increased $6.00. We also see that each inch of water, from 1 through 16, increases the net return by $12 to $13. This example as presented uses the same increased costs as additional water is applied. In reality, costs increase as yield increases because of additional seed, fertilizer, harvesting, trucking, and storage. Often when water is purchased from an irrigation organization, water costs increase as additional water is applied above a basic rate. **To know what each increment of water applied is costing and buying is necessary.**

Summary: Under the conditions set forth in this example profits will be maximized at the application rate of 16 inches net, or 20 inches gross, irrigation water applied. Even if the water and its application were free, it would not be rational to apply more than 16 inches. One can also see that if there is a change in the cost of water and its application or in the price of corn, or both, this relationship shifts and thus a change occurs at the point where profits are maximized.

One of the dangers of an analysis of this type is that assumptions need to be made concerning costs and returns of the enterprise. Anytime a change occurs in the costs or prices, the cost-price relationship changes and a new point of profit maximization is established. The procedure, however, should be useful regardless of the relationships and assumptions that exist.

Note: Marginal cost - marginal return analysis does not apply when growing crops where quality of the product is more important than yield. Providing adequate irrigation water at critical growth periods is paramount for desirable product quality, such as for fresh vegetables, potatoes, melons, berries, fruits, and sweet corn. Reduced or even increased water application without knowing what the result is can mean potential total crop failure; i.e., unable to produce and sell an acceptable quality product. Other local needs, such as frost protection, temperature control, chemigation, and seed germination, may require additional water over that necessary for desirable crop production. For annual crops, such as truck crops, a marginal cost - marginal return analysis can be done, but by using planted acreage as the variable where the product yield is held constant. With most truck crops, adequate soil moisture for the full growing season must be available to obtain desirable yield and product quality. Good water management is where applied water can serve two purposes—crop cooling and crop water needs. However, this may not always be the case. For example, frost protection typically occurs when winter carryover soil moisture is high and crop evapotranspiration has not started yet.

Figure 11–1 Product yield vs. water applied—irrigated corn

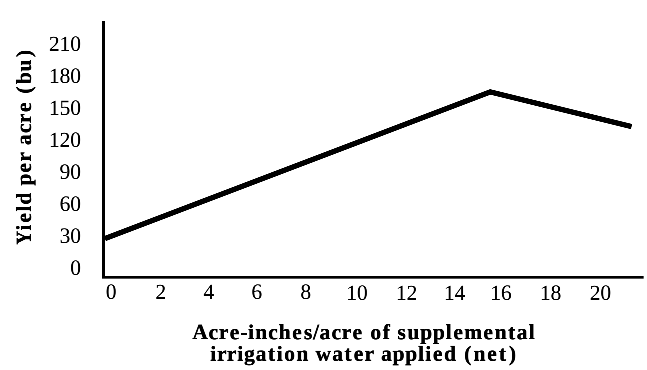

Table 11–4 Marginal cost - marginal return relationships

- - - Water applied 1/ - - - gross (ac-in)	net (ac-in)	Total yield 2/ (bu/ac)	Change in yield 3/ (bu/ac)	Incremental change 4/ (ac-in)	Water cost 5/	Returns above variable costs 6/
0	0	40.0 7/				
1.3	1	47.4	7.4	1	$ 6.00	$ 11.25
2.6	2	55.6	8.2	1	6.00	12.46
4.0	3	63.8	8.2	1	6.00	12.46
5.3	4	71.8	8.1	1	6.00	12.31
6.6	5	80.1	8.2	1	6.00	12.46
8.0	6	88.3	8.2	1	6.00	12.46
9.3	7	96.4	8.1	1	6.00	12.31
10.6	8	104.6	8.2	1	6.00	12.46
12.0	9	112.8	8.2	1	6.00	12.46
13.3	10	121.0	8.2	1	6.00	12.46
14.6	11	129.1	8.1	1	6.00	12.31
16.0	12	137.3	8.2	1	6.00	12.46
17.3	13	145.5	8.2	1	6.00	12.46
18.6	14	153.7	8.2	1	6.00	12.46
20.0	15	161.8	8.1	1	6.00	12.31
21.3	16	170.0	8.2	1	6.00	12.46 8/
22.7	17	165.7	–4.3	1	6.00	–11.48
24.0	18	161.5	–8.5	1	6.00	–22.70
25.3	19	157.2	–12.8	1	6.00	–34.18
26.7	20	153.0	–17.0	1	6.00	–45.39

1/ Gross and net inches of irrigation water applied at 75% application efficiency (from table 11–3).
2/ Corn yield at various amounts of irrigation water applied, assuming an increase of 1 acre-inch water application represents about an 8-bushel increase in yield (from table 11–3).
3/ Change in yield divided by net inches of water applied; i.e.:

$$46.7 - 40.0 = \frac{6.7}{1} = 6.7$$

$$55.2 - 40.0 = \frac{15.2}{2} = 7.6$$

4/ Incremental change in net irrigation water applied.
5/ Cost of applying one additional acre-inch (net) of water by irrigation with an application efficiency of 75%; i.e., 1.33 ac-in x $4.50/ac-in = $5.99, use $6.00.
6/ The additional net return resulting from applying that last acre-inch (net) of irrigation water. Increased variable costs = $2.67/bu – $1.15/bu = $1.52/bu of net income because of increase, or 7.4 bu x $1.52/bu = $11.25. The $6.00 per acre-inch cost of water is included in the $66.00 increased operating cost used in exhibit 11–7.
7/ Actual yield.
8/ Decrease in returns is the result of less than adequate irrigation scheduling on an average year.

A format for an example partial budget is displayed in exhibit 11–9. In this example a quick economic analysis is made to determine the feasibility of owning a combine rather than using custom services. As the example shows, owning the combine is more costly. Factors other than up front costs enter into the decision of owning a combine (or any piece of equipment) rather that fitting into the schedule of a custom service, such as the timeliness of when harvesting could be done.

Exhibit 11–9 Format for developing a partial budget

Proposed Change: Purchasing combine to replace custom harvesting

Additional cost ($)		Additional income ($)	
Fixed costs:		None	
Depreciation	$ 5,000		
Interest	1,600		
Taxes	50		
Insurance	50		
Variable costs:			
Repairs	800		
Fuel, oil	600		
Additional labor	500		
Reduced income ($)		**Reduced costs ($)**	
None		Custom combining charge	$ 8,000
(A) Total annual additional costs and reduced income	$ 8,600	(B) Total annual additional income and reduced costs	$ 8,000
			– $ 8,600
		Net change in profit (B minus A)	–$ 600

652.1105 Pipeline installation and pumping costs evaluation

The purchase and installation of an irrigation pipeline can be a big investment for a land user. It is an investment, the cost of which can be spread over several years covering the life of the loan or the life of the pipeline and appurtenances. Yet, too often pipeline materials are purchased and installed based only on first cost without adequate economic considerations. A good engineering design attempts to optimize materials and power costs for the expected life of the project or loan term.

The method of analysis described here includes average annual pipeline installation cost plus annual energy costs to determine the lowest annual cost for a given flow and total pumping pressure head condition. An example is the best way to demonstrate the process (example 11–1). Electric energy is used to demonstrate this process in this example. The process is the same for any type energy fuel used since the basis for pumping costs comparison is dollars.

Example 11–1 Pipeline installation and pumping costs evaluation

The landowner wants to install a new electric powered pump and buried mainline to provide water to a center pivot covering 150 acres. Keeping the installation cost as low as possible is desired, but it is not know if this will be the most economical way over the life of the pipeline.

Given:

- Pipeline length is 2,000 feet from pump to center of pivot
- Flow is 1,000 gpm (2.23 ft^3/s)
- Operating head not including delivery pipeline friction loss = 43 lb/in^2 (100 ft)
- Pump operates 1,000 hours per year
- Expected life of pump and pipeline is 20 years
- Electric power rates are $.04 per kwh with an estimated 7% annual rate increase

Solution:

1. Pipeline hydraulics: Use PVC irrigation pipe (IPS, class 125), 1,000 gpm

Pipeline hydraulics analysis

Pipe diam. (in)	Friction 1/ loss for 100 ft (ft)	Total loss loss for 2,000 ft (ft)	Operating head required (ft)	Total dynamic head (ft)	Velocity 2/ (ft/s)
6	4.8	96.0	100	196.0	11.3
8	1.3	26.0	100	126.0	6.4
10	0.45	9.0	100	109.0	4.1
12	0.2	4.0	100	104.0	2.8

1/ Calculated using Hazen-Williams equation with C = 150.
2/ Nominal diameter used for velocity calculation.

2. Find fixed cost: Pipeline installation

Fixed costs - pipeline materials and installation

Pipe diam. (in)	Install 1/ cost ($/ft)	Install total cost ($)	Average annual cost 2/ ($/yr)
6	3.35	6,700.00	733.98
8	5.60	11,200.00	1,226.96
10	8.75	17,500.00	1,917.12
12	12.25	24,500.00	2,683.97

1/ Includes pipe and installation, 1994 costs.
2/ Amortized over 20 years at 9% interest, (multiplying factor = 0.10955). To determine annual cost, multiply installed total cost by amortization factor.

Example 11–1 Pipeline installation and pumping costs evaluation—Continued

3. Find variable costs: Energy required for pumping

Variable costs - energy

Pipe diam. (in)	Total head req. (ft)	- - - Energy required - - - (bhp) 1/	(kwh) 2/	Annual energy requirement (kwh) 3/	Annual energy cost ($/yr) 4/	Average annual energy cost ($/yr) 5/
6	196	70.7	94.8	94,800	$3,792	$5,360
8	126	45.5	61.0	61,000	2,440	3,449
10	109	39.3	52.7	52,700	2,108	2,979
12	104	37.5	50.3	50,300	2,112	2,935

1/ Calculated from equation, $\text{bhp}=\frac{\text{gpm}\times\text{head}}{3,960\times\text{Eff}}$ (with overall pumping plant efficiency = 70%).

2/ Calculated from equation, 0.746 bhp = 1 kw.
3/ Energy required multiplied by 1,000 hr/yr.
4/ Annual energy requirement multiplied by energy cost @ $ 0.04 per kwh.
5/ Annual energy cost multiplied by factor 1.41341 (represents an estimated 5% yearly energy cost escalation at 10.5 interest rate for 20-year evaluation period).

4. Most economical pipe size: Using annual cost method

Most economical pipe comparison

Pipe diam. (in)	Total fixed annual cost ($/yr)	Average annual energy cost ($/yr)	Total annual cost ($/yr)	
6	$ 734	$ 5,360	$ 6,094	
8	1,227	3,449	4,676	← **most economical size**
10	1,917	2,979	4,896	
12	2,684	2,985	5,669	

Conclusion: The 8-inch diameter pipe is the most economical size for the given conditions of pipe installation cost and pumping cost. However, annual cost for 10-inch diameter is not much higher. If energy costs escalate higher than estimated, 10-inch diameter would have been the best choice. Because of the cost variability in PVC pipe, it may be worthwhile to evaluate other class pipe; i.e., class 100 or 85 (with necessary pressure control devices). Where competitive priced energy fuels are available, it may also be worthwhile to compare pumping plants using different energy sources. Typically, the most economical pipe size has velocities in the range of 4 to 6 feet per second. Other costs, such as sales tax for purchasing pipe materials and annual maintenance for pipeline, can be included at option of the consultant. This analysis can be used to compare benefits of converting from a high pressure system to a low pressure system. The only item that needs changing is the column, *Operating head requirement*, in the pipeline hydraulics analysis tabular information in solution 1 of the example.

A simple economic analysis for calculating annual energy savings with a pressure reduction can also be used. When everything remains constant except changing the operating pressure, the following equation can be used. This equation does not account for escalating energy costs, but the factor from table 11–6 can be used as a multiplier to estimate the average annual energy costs for a desired period of evaluation time.

Energy savings:

$$\text{kWh} = \frac{(\text{A})\times(\text{ac-inch/ac/yr})\times(\text{lb/in}^2)\times(0.2)}{\text{E}}$$

Where:

kWh	=	seasonal energy savings, in kilowatt hours per year
A	=	area of the field, in acres
ac-in/ac	=	water applied per season, in ac-in/ac/yr
lb/in^2	=	pressure reduction at sprinkler, in lb/in^2
0.2	=	units conversion
E	=	overall pumping plant efficiency, as a decimal

Example 11–2 Calculating annual energy savings

Given:

- An irrigation system for 40 acres.
- Operation pressure presently is 55 lb/in^2. After conversion operating pressure will be 35 lb/in^2.
- Seasonal gross irrigation application is 18 inches.
- Pumping plant overall estimated efficiency is 70%.
- Electric energy cost is $ .04 per kWh.

Solution:

$$\text{kWh} = \frac{(\text{A})\times(\text{ac-inch/ac/yr})\times(\text{lb/in}^2)\times(0.2)}{\text{E}}$$

$$= \frac{40\times 18\times 20\times 0.2}{.70}$$

$$= 4{,}114 \text{ kWh per year}$$

Dollars saved at $0.04 per kWh:

$$4{,}114 \text{ kWh} \times \$.04/\text{kWh} = \$165 \text{ per year}$$

Table 11–5 Typical energy consumption

Energy source	- - - - - - Consumption per unit of fuel - - - - - - Whp-hrs	Bhp-hrs 1/
Electric	0.9 per kWh	1.18 per kWh
Gasoline	8.7 per gallon	11.3 per gallon
Diesel	11.0 per gallon	14.8 per gallon
Propane	6.9 per gallon	8.9 per gallon
Natural gas	6.7 per 100 ft^3	8.5 per 100 ft^3

1/ Calculated based on a reasonable operating efficiency.

Table 11–6 Equivalent energy annual cost escalation factors

Borrowing interest (%)	No. of years	- - - - - Energy cost escalation rate - - - - - 5.0%	7.0%	9.0%
7.0	5	1.09788	1.13970	1.18311
	10	1.22416	1.33069	1.44838
	15	1.35331	1.53928	1.75795
	20	1.48369	1.76451	2.11595
9.0	5	1.09591	1.13685	1.17934
	10	1.21520	1.31715	1.42960
	15	1.33140	1.50456	1.70734
	20	1.44221	1.69553	2.01020
10.5	5	1.09445	1.13476	1.17658
	10	1.20869	1.30733	1.41599
	15	1.31580	1.47988	1.67145
	20	1.41341	1.64783	1.93738
12.0	5	1.09303	1.13271	1.17387
	10	1.20237	1.29780	1.40279
	15	1.30091	1.45639	1.63734
	20	1.38659	1.60357	1.87003

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