Technical note

Cost-estimating procedures for drip-, micro- and furrow-irrigation systems

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Abstract

The total annual fixed and operating costs of a drip-, micro- and furrow-irrigation system were estimated, as well as the marginal factor cost of water applied. An existing centre-pivot irrigation cost-estimating procedure was used. The type of irrigation system data needed are specified. The assumptions about the salvage value and expected lifespan of the system components are given. The total investment cost of the drip-, micro- and furrow-irrigation system is R200 000, R277 586 and R132 012 respectively. The total annual fixed and operating costs of the drip-, micro- and furrow-irrigation system are R28 509, R39 817 and R17 763 (fixed) and R36 957, R38 980 and R106 375 (operating) respectively. The marginal factor cost of water applied for the drip-, micro- and furrow-irrigation systems is R2.00/mm·ha, R1.90/mm·ha and R2.20/mm·ha. The proper estimation of irrigation costs is critical for irrigators to be able to evaluate efficient water use techniques.

Keywords: irrigation system costs, drip-/micro-/furrow-irrigation, cost-estimating procedures

Introduction

The first step in the analysis of the economics of irrigation is to estimate the costs of the irrigation system. The procedures should illustrate how the total annual fixed and operating costs of the system are estimated, as well as the marginal factor cost of applied water.

A monograph (AAEA, 1998) was prepared by a task force organised by the American Agricultural Economics Association (AAEA) to recommend standardised practices for generating costs after a careful examination of the relevant theory and the merits of alternative methods. Among other things the task force developed procedures to estimate irrigation operating costs. Extension economists in the arid west of the United States of America developed useful guides to estimate irrigation system costs (Selley, 1997), and to evaluate different irrigation distribution systems (Llewelyn et al., 1998). In South Africa, a comprehensive *Irrigation Design Manual* (Agricultural Research Council, 1999) was published in 1996 and revised in 1999. The Water Research Commission (WRC) funded a research project in which a cost-estimating procedure for centre-pivot irrigation was developed and illustrated (Oosthuizen, 1991). The cost-estimating procedure was subsequently extended for dragline irrigation systems in another WRC-funded project (Oosthuizen et al., 1996; Breytenbach, 1994). A computer program and guide were developed to illustrate the cost-estimating procedures for centre-pivot and dragline irrigation systems with WRC funding (Meiring et al., 1995).

The purpose of this note is to illustrate that the cost-estimating procedures for centre-pivot and dragline irrigation systems (Meiring et al., 1995) can be extended to include drip-, micro- and furrow- irrigation systems. The objective is to use the existing cost-estimating procedure to calculate the total annual costs of drip-, micro- and furrow-irrigation systems. The next step in the analysis of the economics of irrigation is to estimate the economic profitability and financial feasibility of the irrigation systems using the net present value method which is not the focus of this note.

Methodology

A WRC-funded research project was carried out in the Onderberg region of Mpumalanga Province to analyse the economics of the most important irrigation systems (Oosthuizen et al., 2005). A survey was conducted among 74 farmers to gather farming and financial data to compile farm case studies. A total of 32 irrigation system combinations were identified, including 3 farm sizes and 12 crop combinations. An agricultural engineer (Radley, 2002) designed the drip-, micro-, centre-pivot and dragline systems, while another engineer (Stimie, 2002) designed the furrow irrigation system. The crop water requirements for sugarcane under furrow irrigation and for orchards (oranges) were estimated with the SAPWAT-model (Van Heerden, 2002).

The specifications of the drip-, micro- and furrow-irrigation systems are given in Table 1. The furrow irrigation system was designed to irrigate 25.2 ha sugarcane on a loam soil. The pump rate is 100 m^3/h. The electric motor size is 7.5 kW. The balancing dam capacity is 1 300 m^3.

The drip- and micro-irrigation systems can irrigate 24.8 and 24.9 ha respectively. Each system consists of a 15 ha and 10 ha unit. Each unit consists of six blocks. The pump rate is 48 m^3/h for drip- and 90 m^3/h for the micro-irrigation system. The electric motor sizes are 7.5 kW (drip) and 15 kW (micro).

Table 1 summarises the assumptions about repair and maintenance costs, and gives the investment cost as well as the costs of water, electricity, insurance and labour.

Only cost items that are directly associated with the relevant irrigation system are identified. Costs related to crop produc-

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TABLE 1
Specifications, assumptions and prices of a drip-, micro- and furrow irrigation system in the Onderberg area, Mpumalanga Province, 2002

Irrigation System	Drip	Micro	Furrow
Crop	**Oranges**	**Oranges**	**Sugarcane**
Unit size (ha)	24.8	24.9	25.2
Planned water use (mm/ha·yr)	718	814	1917
Water charge (c/m^3)	13.98	13.98	13.98
Electricity: fixed payment (R/month)	134.53	134.53	134.53
Electricity 0-600 kWh (c/kWh)	31.97	31.97	31.97
> 600 kWh	18.38	18.38	18.38
Insurance tariff: Pump station (%)	0.92	0.92	0.92
Filter station (%)	0.92	0.92	-
Labour costs (R/hour)	3.65	3.65	3.65
Repair and maintenance costs (% of purchase price/1 000 h·yr)			
Centrifugal pump	2.0	2.0	2.0
Electric motor	0 4	0.4	0.4
Underground pipes	0.2	0.2	0.2
Balancing dam	-	-	0.5
Laser levelling	-	-	0.0
Filter station	5.0	5.0	-
Branch line	1.5	1.5	-
Laterals	0.0	0.0	-
Real interest rate (%)	5.0	5.0	5.0
Initial investment cost (R)	200 000	277 586	132 012

tion are thus excluded. The cost-estimating procedures for drip-, micro- and furrow-irrigation are based on the four-step centre-pivot cost procedure (Oosthuizen et al., 1991). Firstly, the physical items and their prices are identified. Then the capital investment and fixed costs are estimated. Thirdly, the operating costs are estimated, and finally a summary of all the costs is given.

The estimation of certain cost components requires explanation. A fixed cost is a cost that occurs no matter what or how much is produced. For an irrigation system it usually includes depreciation, interest, insurance and the fixed electricity charge. The fixed costs are based on the initial investment. The capital recovery method is used to estimate depreciation and interest costs because it is more accurate than the traditional method where depreciation and interest are estimated separately. The formula is:

Capital recovery = [(purchase price – salvage value) x (capital recovery factor)] + [(salvage value) x (real interest rate)]

The capital recovery factor = $i/100(i/100+1)^n/[i/100+1)^n-1]$

where:
- i = real interest rate and
- n = lifespan (in years) of the component.

The real interest rate must be used when current purchase prices are used; with historical prices, the nominal interest rate must be used. The formula for calculating the real interest rate is

$i = (1 + r)/1 + f) – 1$

where:
- i = real interest rate
- r = nominal interest rate and
- f = inflation rate.

The operating costs of the irrigation system should be based on the annual planned water applications. Operating or variable costs are those over which the irrigator has control in the short run. All the operating costs, namely electricity, water, labour and repairs should be estimated as cost/m^3 water pumped so that the marginal factor cost of water applied can be calculated.

TABLE 2
Irrigation system components, salvage value and expected lifespan of irrigation systems in the Onderberg area, Mpumalanga Province

Drip/micro irrigation system		
Component	**Salvage value (% of initial investment cost)**	**Expected lifespan (years)**
Centrifugal pump	15	15
Electric motor	20	15
Underground pipes	30	20
Filter station	0	10
Branch line	5	15
Laterals	0	7
Furrow irrigation system		
Component	**Salvage value (% of initial investment cost)**	**Expected lifespan (years)**
Centrifugal pump	15	15
Electric motor	20	15
Underground pipes	30	20
Balancing dam	0	20
Laser levelling	0	6

The techno-economic coefficients of a relevant irrigation system such as life-span, salvage value, efficiencies and repairs vary according to physical conditions, annual use, and management practices. Therefore, the cost-estimating procedures should provide for the use of different components and techno-economic coefficients. The coefficients include the salvage value and lifespan of the components of the relevant irrigation system, as well as repairs and maintenance. The techno-economic coefficients are given in Table 2.

TABLE 3
Annual fixed costs of a drip-, micro- and furrow-irrigation system in the Onderberg area, Mpumalanga Province, 2002

Irrigation System	Drip	Micro	Furrow
Crop	Oranges	Oranges	Sugarcane
Annual interest and depreciation (R)	26 689.19	37 985.50	16 070.00
Insurance costs (R)	212.32	217.24	79.23
Electricity: basic charge/yr (R)	1 614.36	1 614.36	1 614.36
Total annual fixed cost (R)	28 509.87	39 817.10	17 763.61

Results

The results are the estimated total annual fixed and operating costs for drip-, micro- and furrow-irrigation. The worksheets for each system with the equations are documented in Oosthuizen et al., 2005.

For each system, the following steps are illustrated. The first step is to calculate the investment in the components of the irrigation system (Tables 1 and 2). Then the depreciation and interest costs are estimated, as well as insurance and fixed electricity costs (Table 3).

The total investment cost of the drip-, micro- and furrow-irrigation systems is R200 000, R277 586 and R132 012 respectively (Table 1).

The total fixed cost is R28 509, R39 817 and R17 763 for the drip-, micro- and furrow-irrigation systems respectively (Table 3).

The next step is to estimate the operating costs of the systems (water, electricity, labour and repairs (Table 4)). The number of pumping hours is derived from the amount of water pumped annually which depends on the crop water requirements and area irrigated. The electricity cost is based on the total electricity used (kWh) by operating the system at the different charging rates. Firstly, the volume of water pumped must be estimated which depends on the area under irrigation and the crop water requirements. The number of hours pumped is calculated by dividing the water pumped by the pump rate. Secondly, the electricity use is estimated for pumping the water. Thirdly, the total electricity cost is estimated by multiplying the electricity use for pumping the water with the high and low electricity charge.

TABLE 4
Annual operating costs of a drip-, micro- and furrow-irrigation system in the Onderberg area, Mpumalanga Province, 2002

Irrigation System	Drip	Micro	Furrow
Crop	Oranges	Oranges	Sugarcane
Water pumped (m^3)	178 388	202 725	483 084
Hours pumped	3 716	2 253	7 831
Total water cost (R)	24 938.70	28 340.97	67 535.14
Electricity consumption/hour (kWh)	7.5	15.0	7.5
Total electricity use (kWh)	27 873	33 788	36 231
Total electricity cost (R)	6 088.61	7 175.16	7 624.83
Labour hours required/yr	517	310	8 116
Total labour costs (R)	1 884.55	1 131.65	29 600.14
Total annual repairs and maintenance costs (R)	4 045.52	2 331.97	1 615.43
Total annual operating costs (R)	36 957.38	38 980.05	106 375.54

TABLE 5
Summary of the total annual costs of a drip, micro and furrow irrigation system, the cost allocation, and the marginal factor cost, Onderberg area, Mpumalanga Province, 2002

Irrigation System	Drip	Micro	Furrow
Total annual ownership/fixed cost (R)	28 509.87	39 817.10	17 763.61
Operating costs (R)			
Electricity	6 088.61	7 175.66	7 624.83
Water	24 938.70	28 340.97	67 535.14
Labour	1 884.55	1 131.65	29 600.14
Repairs and maintenance	4 045.52	2 331.77	1 615.43
Total operating costs (R)	36 957.38	38 980.05	106 375.54
Total annual fixed and operating costs (R)	65 467.25	78 797.15	124 139.15
Cost allocation per unit			
Fixed costs/ha (R)	1 147.50	1 598.77	352.45
Labour cost/m^3 water pumped (R)	0.0106	0.0056	0.0613
Repairs and maintenance/m^3 (R)	0.0227	0.0115	0.0033
Electricity costs/m^3 (R)	0.0287	0.0306	0.0138
Water costs/m^3 (R)	0.1398	0.1398	0.1398
Marginal factor cost of water applied (R/m^3)	0.2018	0.1875	0.2182

The total annual labour cost depends on the wage rate (*Basic Conditions of Employment Act,* 2002) and the number of labour hours required. The number of labour hours required depends on the hours pumped and the labour hours required per 24 h of irrigation. The *Irrigation Design Manual* gives the labour requirements for the different irrigation systems (Burger et al., 1999).

The total annual repairs and maintenance costs of the irrigation systems are estimated based on the percentage of purchase price/1 000 h·yr for each component (Table 1). The total annual operating cost of the drip-, micro- and furrow-irrigation systems is R36 957, R38 980 and R106 375 respectively. The total operating costs of the furrow irrigation system is the highest because of the crop (sugarcane), the water use and labour use. Table 5 gives a summary of the total annual costs of the irrigation systems, the costs/m^3 water pumped and the marginal factor cost. The total annual fixed and operating costs of the drip-, micro- and furrow-irrigation system are R65 467, R78 797 and R124 139. The marginal factor cost of water applied for the drip-, micro- and

furrow-irrigation systems is R0.20/m^3, or R2.00/mm·ha, R0.19/m^3 or R1.90/mm·ha, and R0.22/m^3 or R2.20/mm·ha.

The marginal factor cost for an application of 25 mm on approximately 25 ha is R1 250, R1 187.50 and R1 375 for the drip-, micro- and furrow-irrigation systems. Thus, for decision-making purposes the irrigator must decide whether the expected additional crop income will for example cover the above-mentioned irrigation application costs.

Conclusion

The proper estimation of irrigation costs is critical for irrigators to be able to evaluate efficient water use techniques. Computer worksheets were developed to estimate the irrigation costs of a drip-, micro- and furrow-irrigation system and the results were demonstrated in this note. The main result is that the existing cost estimating procedures of centre pivot- and dragline-irrigation systems were extended to estimate the total annual irrigation costs of drip-, micro- and furrow-systems. The equations used in calculating these costs are documented. In addition, the cost of an extra irrigation application can be estimated, which is valuable information needed to decide how much to irrigate.

These computerised cost-estimating procedures can therefore be used to estimate the total fixed and operating costs of the major irrigation systems. These procedures are suitable for on-farm use by irrigators and advisors to decide over the long run which irrigation systems to buy, and in the short run how to manage the operating costs that are linked directly to the decisions of how much, how and what to produce. The procedures can also be used to consider changes in a current irrigation system or to evaluate the feasibility of switching to a more water-efficient system. It also may be useful for research regarding the economic viability of various irrigation systems, because it provides a systematic way to determine the annual total costs of the systems.

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