COST AND RETURNS ASSOCIATED WITH THE INSTALLATION AND USE OF IRRIGATION SYSTEMS

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The economics of irrigation vary considerably throughout the major citrus-producing areas of the world. The climate, topography and soil characteristics determine the need for irrigation; however, these factors are essentially given at any grove or orchard location and hence are uncontrollable except at time of purchase. The controllable factors affecting the costs and returns of citrus irrigation are of more interest. This is where I shall concentrate in today's presentation of a decision-making framework. A computerized "University of Florida Economics of Citrus Irrigation Game" will then be introduced. Here, you will assume the role of a manager of a Florida citrus grove and will be required to make specified irrigation decisions.

ECONOMIC REASONS FOR IRRIGATION

There are 3 major economic reasons for irrigating. These are for survival, insurance, and to maximize returns.

It is a necessity to irrigate for crop survival or to cover production costs in many citrus-producing regions. This is not the case in most parts of Florida and it was only recently that a yield response from timely irrigation for Florida citrus was shown.

It may be necessary to install an irrigation system to be used during an extreme drought situation in the unpredictable rainfall-evaporation system we have in Florida. This limited irrigation may be economically justified to provide the necessary cash flow to remain in production.

The third reason for irrigation is to maximize returns. This is particularly relevant for Florida, since supplemental irrigation may be used to maintain adequate soil moisture throughout the production period to maximize yields. Water supplied through irrigation has a different economic value depending upon the time of its application because of rainfall distribution. It may not pay to irrigate under some circumstances if the yield response is not sufficient.

MEASURING THE COSTS AND RETURNS

The expected costs and benefits must be quantified and projected over the planning horizon to evaluate whether irrigation is economically justified (*i.e.* benefits exceed costs) or to select an irrigation system and level of irrigation.

Benefits

The direct benefit from irrigation is increased yields. The yield response from irrigation must be examined for the specific grove and variety situation. More boxes should mean greater returns to the individual grower, but price expectations play an important role since both yield and price determine revenues.

Other benefits such as increases in fruit size for fresh fruit growers and pounds-solids per acre for processing fruit need to be considered. More difficult to measure and to express in value units are benefits such as cold protection, and automation in fertilizer and pesticide application.

Costs

The costs of citrus irrigation can be measured with some reliability. Installation costs and seasonal operating costs should be readily available. However, it may be difficult to measure all costs since some are difficult to quantify, such as effects on internal fruit quality from over-irrigation. Analyzing the cost of a blockage in a drip irrigation system is next to impossible. Further problems are introduced because of the uncertainty of irrigation requirements in a given season.

A partial budgeting approach should produce a more

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informed decision, regardless of the difficulties of coming up with numerical values for the costs and returns from irrigation, than if there was no attempt to quantify the costs and benefits.

Added Costs vs Added Returns

It is economically worthwhile to incur additional costs up to the point where the improvement in the returns exactly equals the increased cost. It is not worth experiencing additional costs beyond this point since the additional returns will not cover these costs. What this means is that you should be willing to invest a dollar if you know that you will receive more than a dollar back. It is not a good investment if the return drops below a dollar.

An illustration based upon the work of Koo (1) and Reuss (3) should show how this concept can be applied to an irrigation decision. The average yield response for 'Hamlin' oranges over a 6-season period was:

Level of irrigation[2]	Average boxes per acre[3]
	607
II	722
III	818
IV	827

Take the costs of the 4 levels of irrigation as 100 (where 607 boxes per acre = 100), 111, 123 and 145 dollars per acre, respectively, for I through IV and the on-tree price of fruit at $2.00 per box. The net return above irrigation expenses can be calculated as 1,114, 1,333, 1,513 and 1,506 dollars per acre respectively. Thus, Level III would be selected as the optimum level. This level is preferred to I or II because additional costs are offset by increased revenues. However, this is not the case when moving from Level III to IV.

DECISION FRAMEWORK

A decision framework can be briefly outlined for your suggested use when selecting a specific irrigation system. First of all, specific costs and other information, as well as a worksheet will be provided to enable you to complete such an analysis in playing the computer game.

Each manager must assess his individual situation. Capital, labor and other resource availability must be examined along with the soil characteristics and grove or orchard makeup. Certain options may be eliminated because of unique grove characteristics, such as topography.

Next, information on the costs and requirements of the systems to be considered should be assembled. Data on the installation costs, labor requirements, water requirements, energy requirements, annual operating costs and annual fixed costs should be analyzed.

These controllable factors, along with the design of the system, must be matched with the available resource base. A partial budget for the irrigation activities can be developed to consider the alternatives. Built in are assumptions on life expectancy, reliability, size of the system, depreciation, frequency of irrigation and water requirements. Expressing the costs on a per acre or per hectare, per application, and per acre-inch or per ha-cm basis should enable detailed comparisons.

When this analysis is completed, the decision is ready to be made. This analysis, revealing the numbers, then becomes one input into the decision-making process. It is the decision maker's responsibility to synthesize this information with the non-quantifiable factors, the possibility of technological improvements causing obsolescence and the uncertain factors such as prices and rainfall distribution, and to come up with the best choice for his own situation.

UNIVERSITY OF FLORIDA ECONOMICS OF CITRUS IRRIGATION GAME[4]

Management decision games are designed for educational purposes. It is the purpose of this game to emphasize the economics of the decisions made in selecting an irrigation system for Florida citrus groves. Computerized games are designed to approximate real situations. However, no game can exactly represent the actual situation but the game should be viewed as a means to improve the manager's decision-making abilities.

This game is established for a specific grove situation in Florida. It should be of value, however, to citrus managers in other citrus-producing areas since the same type of decisions must be made. The analyses required would be the same with specific cost and return information unique to each area.

General Description

The game draws heavily on previous irrigation system research and requires the analysis of the options available for irrigating a Florida citrus grove. Each individual or team participant must decide the type of irrigation system to install, the size of the system (number of acres or hectares) and the level of irrigation (application rate).

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[2] I = no irrigation; II = irrigate at 2/3 depletion; III = irrigate at 1/3 depletion, Jan.-Jun., 2/3 remainder; IV = irrigate at 1/3 depletion thru year.

[3] 10 boxes per acre equals 1 metric ton per ha.

[4] Appreciation is expressed to Dalton Harrison, Agricultural Engineering Department, for his assistance in developing this game and to Sheriar Irani for the computer programming.

Decisions are made only once and the outcome is projected over a 5-year planning horizon. Given are costs of installation and costs of operating with specified water and labor requirements for the different systems and sizes. Uncertainty is introduced into the game with seasonal water requirements, fruit yield per acre or hectare and fruit price varying in each of the 5 seasons.

The objective is to maximize average return per acre minus irrigation expenses over the 5-year planning horizon.

Decision Situation

The grove is a 240-acre (96-ha) mature 'Hamlin' orange grove located in the Ridge area in Florida. The soil is Astatula fine sand with a moisture holding capacity of 3.5 inches (8.75 cm) in a root zone of about 5 ft (1.5 m). Tree spacing is 25 x 25 ft (6.6 x 6.6 m). Source of water is a centrally located well with a depth of 200 ft (61 m) and 100 ft (30.5 m) of casing and a pumping lift of 90 ft (27.5 m).

The capital and labor availability are similar to your personal operation.

Decision 1: Irrigation system. You have a choice of 6 irrigation systems or no irrigation as described below. These systems will be designated A through G:

A. Permanent overhead sprinklers. Sprinklers are spread at 75 x 75 ft (22.9 x 22.9 m) in a triangular pattern, operate at medium pressure (50 to 55 psi) and are supported by 21-ft galvanized risers. Application rate is 0.12 inch (3 mm) per hour.

B. Permanent under-tree sprinklers. Pop-up sprayheads or foggers. Risers are 6 to 12 inches (15 to 30.5 cm). Laterals may be above or below ground with sprinklers located under every tree. Operation is at low pressure (30 to 40 psi).

C. Self-propelled guns. Drawn by an auxiliary motor or hydraulic power units, guns move down rows at ground speeds of about 12 inches (30.5 cm) per minute, giving a gross application of 2.2 inches (5.5 cm). Water discharge is above trees, covering a circle approximately 440 ft (134 m) in diameter. High pressure (70 to 85 psi).

D. Portable guns. Same type gun as self-propelled system except is portable and must be manually moved between sets. Applies approximately 1.0 acre-inch (1 ha-cm) per hour.

E. Portable perforated pipe. Aluminum pipe with perforations capable of applying 0.2 to 2.0 inches (5 to 50 mm) per hour. Moved manually. Low pressure (8 to 10 psi).

F. Drip irrigation system. Automatic timing system with 4 emitters per tree. System is run to apply 36 gallons per tree per day. System requires low pressure (15 to 25 psi).

G. No irrigation system.

The yield response in this game is the same regardless of the system selected. This means that the same yield will be achieved with different systems if the same level of irrigation is chosen.

Decision 2: Size of system. The possible sizes of the irrigation system in the grove are 40, 60 and 80 acres (16, 24 and 32 ha). The total acreage in the grove is 240 acres (96 ha), hence there will be 6 units of the 40-acre (16-ha) size, 4 units of the 60-acre (24-ha) size, or 3 units of the 80-acre (32-ha) size. There is no size of system specified if no irrigation system is selected in Decision 1.

Decision 3: Level of irrigation. The application rate decisions follow those described by Koo (2). One of the following levels must be selected:

I. No irrigation.

II. Irrigation at depletion of 2/3 of the readily available moisture in the surface 5 ft (1.5 m) of soil.

III. Irrigation at depletion of 1/3 of the readily available moisture from January through June, but 2/3 for the remainder of the year.

IV. Irrigation at depletion of 1/3 of the readily available moisture throughout the year.

V. Drip irrigation.

A number of factors must be considered in making the above 3 decisions. The known costs and requirements and information on the uncertain factors are presented as well as a suggested method of analysis in the following sections.

Specified Costs and Requirements

One of the most important factors to consider is the cost of irrigation. Expected costs of irrigation should be evaluated with respect to the expected revenues to see if irrigation is economically justified.

Installation costs. Table 1 lists the installation costs for the different irrigation systems and sizes. These costs are for the complete system, including distribution system, pump, well, pipe, traveler and power unit where applicable.

Seasonal costs. The costs of irrigation have variable and fixed cost components. Variable costs are determined by the labor requirements, cost of labor and length of operation. Fixed costs will be the same each year but do vary considerably among systems. The distribution of costs between variable and fixed will likely have a strong influence on the system decision.

Labor costs. Seasonal labor costs will vary depending upon the system, size and the number of applications. Table 2 presents the labor requirements per application. An application with system F (drip irrigation) is defined as lasting 1 week. This enables comparisons with other systems where 1 application is completed in slightly over

1 week. Labor cost per hour is taken at $2.50.

Hours of operation. Hours of operation during a season will vary depending upon the system, the size and number of applications. Table 3 gives the hours of operation per day for the system-size combinations. The hours include set-up and breakdown time where applicable. For systems A - E one application was taken to last 8 days. For system F it was assumed that half the acreage would be irrigated at one time, making 2 sets of 9 hours each.

Non-labor variable costs. Costs of electricity or fuel for the pump, grease, oil and maintenance are a major component in many systems. Table 4 gives the non-labor variable costs per application for the system-size combinations.

Water requirements. Cost comparisons are frequently made on the basis of acre-inches of water applied. Table 5 lists the water required per application for the systems considered. Water costs are taken at zero, since pumping from well.

Fixed costs. The fixed costs per season for the different system-size combinations are listed in Table 6.

Uncertain Factors

Also important in citrus irrigation decisions are the expected supplemental water requirements, the yield response to irrigation, and fruit prices. These factors are to some extent uncontrollable and add uncertainty to the situation.

Water requirements. Approximately 46 inches (1,170 mm) of water per year are required for mature citrus groves in Florida. Much of this can be met by rainfall. However, supplemental irrigation may be desirable because of the rainfall distribution. Supplemental water requirements for this game are developed from Koo's research (1). Over the 6-year period the minimum, maximum and average number of applications are shown in Table 7. The drip irrigation system was assumed to utilize the same number of weeks of operation as Level IV.

Table 1. Installation costs of specified irrigation systems.

System	40 acres[x]	60 acres[x]	80 acres[x]
	Dollars per acre[z]		
A	1,100	1,000	1,200
B	550	600	750
C	375	275	350
D	275	260	300
E	275	250	300
F	410	450	475
G	0	0	0

[x]16, 24 and 32 ha, respectively.

[z]Cost per acre times 2.5 equals cost per ha.

Table 2. Labor requirements per application per acre.

System	40 acres[x]	60 acres[x]	80 acres[x]
	Dollars per acre[y]		
A	.10	.10	.10
B	.10	.10	.10
C	.42	.40	.44
D	2.05	2.64	2.31
E	4.00	3.78	4.03
F[z]	.30	.30	.30
G	0	0	0

[x]16, 24 and 32 ha, respectively.

[y]Cost per acre times 2.5 equals cost per ha.

[z]Requirements per week of operation.

Table 3. Hours of operation for specified irrigation systems.

System	40 acres[x]	60 acres[x]	80 acres[x]
	Hours per day		
A	18.0	18.0	18.0
B	18.0	18.0	18.0
C	11.0	16.5	22.0
D	10.3	9.5	10.3
E	10.5	11.0	10.5
F	18.0	18.0	18.0
G	0	0	0

[x]16, 24 and 32 ha, respectively.

Table 4. Other variable (non-labor) costs per application per acre.

System	40 acres[x]	60 acres[x]	80 acres[x]
	Dollars per acre[y]		
A	4.35	3.56	2.29
B	3.81	3.12	2.01
C	4.55	6.11	5.94
D	3.95	3.74	4.33
E	2.50	2.36	1.45
F[z]	.59	.59	.59
G	0	0	0

[x]16, 24 and 32 ha, respectively.

[y]Cost per acre times 2.5 equals cost per ha.

[z]Cost per week of operation.

Yields. It is necessary that yield be increased such that additional revenues more than offset additional costs to economically justify the expenses of supplemental irrigation. The yield response used in this game is again based on Koo's research (3). The minimum, maximum and average yields for the 6-year study reported are shown in Table 8. Again drip irrigation was taken at Level IV. The effect of irrigation on pounds-solids per box is not considered in this game. A constant 5.69 pounds-solids per box or 1.26 gallons of FCOJ per box is utilized.

Prices. The 2 components which determine revenues are yield and price. Yield may be increased but the realized price may be such in certain years that revenues do not cover the increased irrigation costs. On-tree prices used in this game are selected at random from a normal distribution, such that the mean price is $1.93 per box, with a standard deviation of $0.68 per box. These assumptions result in a probability of 67% that the price will fall between $2.61 and $1.25.

Table 5. Water required per application.

System	Acre-inches[x]
A	2.2
B	2.2
C	2.2
D	2.2
E	2.2
F[z]	.65
G	0

[x]1 acre-inch = 1 ha-cm.

[z]Acre-inches per week of operation.

Table 6. Fixed cost per acre per year.

System	40 acres[x]	60 acres[x]	80 acres[x]
	Dollars per acre[z]		
A	110	100	120
B	55	60	75
C	38	28	35
D	28	26	30
E	28	25	30
F	41	45	48
G	0	0	0

[x]16, 24 and 32 ha, respectively.

[z]Cost per acre times 2.5 equals cost per ha.

Table 7. Water requirements per year.

	Level of irrigation			
		II	III	IV
	No. of applications			
Minimum	0	2	4	6
Maximum	0	5	9	14
Average	0	3	6	9

Making the Decision

How the individual team is organized, division of responsibilities and the analysis conducted is left to team members. Worksheets (Fig. 1) are supplied only as a suggested approach. Select the system, size and level of irrigation to complete the worksheet. Assumptions will have to be made since the water requirements, yield and price are not known. A partial budgeting approach can be followed after this to analyze the net return after irrigation costs. More than one analysis can be made.

Decision form. Indicate the selection on the decision form (Fig. 2) once the decisions have been made using your assigned team number and a team name of your choice. Only numerical entries should be made within the boxes.

Your decisions will be inserted in the computer which will simulate the results of your particular set of decisions. A computer printout which summarizes the outcome will be supplied to each team. This report will list the seasonal values and costs for 5 years and the averages and variation over the 5-year horizon.

OUTCOME OF COMPUTER GAME

Nine of the 16 teams turning in decision forms chose the selection that produced the highest net return after irrigation expenses. The highest net return was generated by the drip irrigation system at the 40-acre size (16 ha), based upon costs and returns presented in the computer game directions.

The average outcome for the selections are shown in Table 9. Detailed comparisons between the 2 selections producing the highest net revenues over the 5-year period are shown in Table 10. The self-propelled gun system has the lower per-acre-inch or per-ha-cm cost but the higher per-acre or per-ha cost, because it required 13.20

Table 8. A yield response to irrigation of 'Hamlin' oranges.

	Level of irrigation			
		II	III	IV
	Boxes per acre[z]			
Minimum	400	511	630	637
Maximum	875	952	1,050	1,071
Average	607	722	818	827

[z]10 boxes per acre = about 1 ton per ha.

Budget of Costs and Returns

System
Size
Irrigation
level

Assumptions

1a. Number of supplemental irrigations
1b. Acre-inches (ha-cm) of water applied per season
2. Yield
3. Price

	Amount required	Cost per acre or hectare	Cost per acre-inch or ha-cm
Variable costs			
Labor			
Other variable			
Fixed Cost		______	______
Total Cost			
Gross return		______	______
Return minus irrigation cost		______	______

What is the fruit price necessary to pay for increased yield? ________
(Divide total irrigation cost by increased yield).

Fig. 1. Worksheet for the computer game.

TEAM NUMBER ________ TEAM IDENTIFICATION ________

(Up to 10 letters)

On this form, indicate the selection of your decisions.

Indicate decisions with numerical response in boxes below.

Decision 1

1. A = permanent overhead
2. B = permanent undertree
3. C = self-propelled guns
4. D = portable gun
5. E = portable pipe
6. F = drip irrigation system
7. G = no irrigation

D 1 [ ]

(CC 20)

Decision 2

1. 40-acre (16-ha) units
2. 60-acre (24-ha) units
3. 80-acre (32-ha) units
4. no system

D 2 [ ]

(CC 30)

Decision 3

1. = no irrigation
2. II = irrigate at 2/3 depletion
3. III = irrigate at 1/3 depletion, January-June, 2/3 remainder
4. IV = irrigate at 1/3 depletion throughout year
5. V = drip

D 3 [ ]

(CC 40)

If you select '7' in Decision 1, please check that you have also selected '4' for Decision 2 and '1' for Decision 3.

Fig. 2. Decision form for the computer game.

acre-inches (ha-cm) of water, compared to 5.98 acre inches (ha-cm) required for drip irrigation.

SELECTED REFERENCES

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Table 9. Average outcome for irrigation selections made during the computer game. Selections not chosen from the available options are omitted.

System	Size (acres)[x]	Irrigation level	Net return after irrigation expenses (dollars per acre)[z]
Drip	40	V	1,390
Self-propelled guns	60	III	1,359
Permanent undertree	60	III	1,349
Portable gun	80	III	1,339

[x]16, 24 and 32 ha, respectively.

[z]Cost per acre times 2.5 equals cost per ha.

Table 10. Cost comparisons between drip irrigation and the self-propelled gun irrigation systems. Values are 5-year averages, as selected in the computer game.

	Drip (40 acres)[x]			Self-propelled guns (60 acres)[x]		
	Dollars			Dollars		
	Per acre[y]	Per acre-inch[z]	Total cost %	Per acre[y]	Per acre-inch[z]	Total cost %
Labor cost	6.90	1.15	13	6.00	.45	8
Other variable cost	5.43	.91	10	36.66	2.78	52
Fixed cost	41.00	6.86	77	28.00	2.12	40
Total cost	53.33	8.92	100	70.66	5.35	100

[x]16 and 24 ha, respectively.

[y]Cost per acre times 2.5 equals cost per ha.

[z]1 acre-inch = 1 ha-cm.