Economics of Surface Water Development For Vegetable Irrigation in S.E. Oklahoma

Bulletin B-785
December 1987

Agricultural Experiment Station
Division of Agriculture
Oklahoma State University

Abstract

This study evaluates the economics of irrigation pond construction and associated irrigation systems for vegetable production in southeastern Oklahoma. A separable programming model was used to determine optimal product mixes and size of irrigation ponds. Estimates were made for three pond construction financing options: 1) individual producer using private funds; 2) six-member irrigation districts using private funds; and 3) six-member irrigation districts using low interest state guaranteed bond funds.

Results indicate producers belonging to irrigation districts and irrigating from multi-member water collection structures can experience larger net cash flows and net returns. It was also determined that producers benefit from using more efficient technology such as handmove sprinklers, which have a higher application efficiency than furrow systems.

This research was conducted under Oklahoma Agricultural Experiment Station Project H-1905

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

Economics of Surface Water Development For Vegetable Irrigation in S.E. Oklahoma

Jeffrey F. Dale
Raymond Joe Schatzer
James R. Nelson[1]

INTRODUCTION

Several agricultural producers in southeastern Oklahoma are currently involved in the production and marketing of horticultural crops. Recent research suggests there may be considerable potential, under certain circumstances, to increase production of horticultural crops in this region, even on small, limited resource farms. (Wickwire, 1985).

Successful production of any agricultural commodity relies on the availability of resources required for production. In particular, adequate water for horticultural crop production is a major concern. Researchers feel adequate water is essential to achieve and maintain product quality and quantity levels present in existing horticultural crop markets.

In much of southeastern Oklahoma, irrigation with water from constructed surface water collection structures (ponds), is economically and technically feasible. Furthermore, research has indicated that economies of size exist in the construction of ponds (Dale, Schatzer and Nelson, 1986). Economies of size will allow producers to increase their total use of water at a decreasing marginal cost per unit of water.

To exploit the economies of size in pond construction, producers may wish to form multi-member irrigation districts. An additional incentive to the development of irrigation districts is that low interest, state guaranteed loan funds may be available as security and collateral for investment certificates issued to raise funds for local entity water and sewer projects (Nelson, 1984). The funds are available for any political subdivision -- county, incorporated town, municipality, school district, or irrigation district. Eligible projects include water supply reservoirs, storage tanks, water treatment and distribution systems, and wastewater treatment and collection systems. Terms for the funds are 8.94 percent annual interest and minimum and maximum payback periods of 10 and 25 years, respectively. The maximum loan amount per project for ratable entities is $12.5 million and for non-ratable entities is $2.5 million (Oklahoma Water Resources Board, 1986).

---

[1]Jeffrey F. Dale is Research Assistant, Raymond Joe Schatzer is Assistant Professor and James R. Nelson is Professor of Agricultural Economics, Oklahoma State University. Report of research conducted under Oklahoma Project 1905.

OBJECTIVES OF THE STUDY

The primary objective of this study is to evaluate the economics of irrigation pond construction and associated irrigation systems for vegetable production in southeastern Oklahoma. Specific objectives addressed in this study are as follows:

1. To estimate, for a representative southeastern Oklahoma vegetable producer, the profit maximizing vegetable crop mix, and the associated potential net return, net cash low, required pond size, and labor requirement.
2. To estimate the potential economic benefit to a representative southeastern Oklahoma vegetable producer of forming a multi-member irrigation district using private funds to support irrigated vegetable production.
3. To estimate the potential economic benefit to a representative southeastern Oklahoma vegetable producer of forming a multi-member irrigation district with low interest state guaranteed bond funds to support irrigated vegetable production.

PROCEDURES

This section includes a description of the analytical procedures used to address the objectives. Necessary data and related resource assumptions are also discussed.

A representative southeastern Oklahoma farm and associated resources are specified. The resource base and management skills of the representative southeastern Oklahoma producer are assumed adequate for the production of the following horticultural crop enterprises: spinach, bell peppers, seeded fall broccoli, transplanted fall broccoli, seeded spring broccoli, transplanted spring broccoli, cantaloupes, cucumbers, okra, snap beans, sweet corn, sweet potatoes, staked tomatoes, watermelons, summer squash or southern peas.

Three scenarios are developed to analyze the objectives. Four acreages (1.0, 2.5, 5.0, and 10.0 acres) and two irrigation technologies (furrow and sprinkler) are analyzed for each of the three scenarios. The furrow system uses ditches between the rows to deliver water to the crop from gated pipe along the edge of the field. The sprinkler system uses sprinklers along hand movable pipe to deliver water from the main line pipe.

Scenario one hypothesizes a representative vegetable producer in southeastern Oklahoma developing on-farm surface water resources (ponds). Profit maximizing crop mixes and associated economic costs, net returns, cash flows and labor requirements are estimated.

Scenario two addresses the benefits accruing to the same representative producer from participating in a six member irrigation district (6 members are assumed since 6 is the minimum number required for the district to be eligible for the state guaranteed funds). The district would be financed using private funds at competitive interest rates. The potential economic benefit accruing to the district members is measured by comparing estimated costs, net returns and cash flows with those results generated in scenario one.

Scenario three addresses the benefits from financing the pond construction and irrigation systems with the low interest state guaranteed bond funds. The potential economic benefit of the guaranteed bond funds to the district members is measured by comparing estimated costs, net returns and cash flows with estimates generated in scenario two.

Development of the Model

Initially, a cost curve representing the construction cost for ponds suitable for horticultural crop irrigation in southeastern Oklahoma is calculated. The cost for eighteen ponds is calculated in accordance with the method detailed below. The cost curve relates construction cost in dollars to acre inches of water storage capacity. The curve exhibits a declining marginal cost of water as the size of the structure increases.

A linear programming model developed by Wickwire is modified and used to analyze the scenarios. Modifications to the model include the removal of all non-vegetable enterprise activities and the inclusion of the annual fixed cost and cash flow requirements for building the complete irrigation system (structure, pump, motor; and distribution system). The cost curve is incorporated into the linear programming model using a linear approximation of the nonlinear relationship to represent the annual debt service and fixed cost associated with each incremental acre inch of water. With the addition of the linearized function representing the per acre inch water costs, the model is designed to maximize net returns to land, management, and non-irrigation capital investments.

The model consists of rows which are either resource constraints or transfer rows which provide a mechanism to transfer a good or service from one activity to another. The model's columns consist of all planting, borrowing, hiring, and selling activities. Included in these columns are the separable activities representing the nonlinear cost curves for irrigation development. Also columns exist for cash flow and water transfer. Column activity parameters represent the quantity of the respective resources required by the activity. Table 1 provides a partial tableau of the model with only one crop represented.

The first colulmns are the spinach production activities for each week spinach can be planted. In the objective function row is a negative value for adjusted variable cost (total variable cost minus labor cost, irrigation cost, and interest on operating capital) for one acre of spinach. Entries in the remaining rows are the requirements of one acre of spinach for each respective resource. In the cash flow rows, for the weeks spinach requires cash, there is a positive coefficient equal to the adjusted variable costs for the week for one acre of spinach. The next few

TABLE 1. PARTIAL TABLEAU OF THE LINEAR PROGRAMMING MODEL

Row Names	Spinach Week 4		→Spinach Week 14	Hire Labor→ Week 1		Hire Labor Week 52	Sell Spinach Week 14		→Spinach Week 24	Transfer Cash Flow Week 1 to→ Week 2		Transfer Cash Flow Week 51 to Week 52
Objective	b	b	b	-5	-5	-5	6.87	a	7.01	.001	.001	.001
Cash Flow Wk 1				5						1		
Cash Flow Wk 2					e					-1.001	d	
Cash Flow Wk 3					e						d	
Cash Flow Wk 4	a				e						d	
↓	a	a			e						d	
Cash Flow Wk 14	a	a	a		e		-6.87				d	
↓		a	a		e			b			d	
Cash Flow Wk 24			a		e				-7.01		d	
↓					e						d	
Cash Flow Wk 49					e						d	
↓					e						d	
Cash Flow Wk 52						5					d	-1.001
Capital Week 4												
Capital Week 8												
↓												
Capital Week 48												
Capital Week 52												
Spinach Yield 14	-400						1					
↓		b						c				
Spinach Yield 24			-400						1			
Labor Week 1				-1								
↓					-c							
Labor Week 4	a				-c							
↓	a	a			-c							
Labor Week 14		a	a		-c							
↓	a	a	a		-c							
Labor Week 52						-1						
Land Week 1												
↓												
Land Week 4	1											
↓	1	c										
Land Week 14	1	c	1									
↓		c	c									
Land Week 52												
Water Week 1												
↓	a	a										
Water Week 13	a	a										
↓	a	a										
Water Week 52												
Water Supply												

a is a positive coefficient or zero. b is a negative coefficient or zero. c is a positive one or zero. d is a negative, positive or zero coefficient. e is five or zero. F is the acreage assumed in the respective scenarios. G is 30 times F.

Borrow Cash Flow Week 1→ Payback Week 4		Borrow Cash Flow Week 1→ Payback Week 52		Borrow Cash Flow Week 49 Payback Week 52	Buy Water→ Week 1		Buy Water Week 52	Irrigation System → Build 1		Irrigation System Build 18	Type	Right Hand Side
-0.0115	b	-0.15	b	-0.0115	b	b	b	b	b	b		
-1	-1	-1			a						L	O
						a					L	O
						a					L	O
1.0115						a					L	O
	d		d			a					L	O
						a					L	O
	d		d			a					L	O
	d		d			a					L	O
	d		d			a					L	O
	d		d	-1		a					L	O
						a					L	O
		1.15	d	1.0115		a	a	a	a	a	L	O
	1	1									L	G
	c	1	c								L	G
	c	1	c								L	G
	c	1	c								L	G
	1	c	1								L	G
											L	O
											L	O
											L	O
											L	O
											L	O
											L	O
											L	O
											L	O
											L	O
											L	O
											L	F
											L	F
											L	F
											L	F
											L	F
											L	F
											L	F
					-1						L	O
						-c					L	O
						-c					L	O
						-c					L	O
							-1				L	O
					1	c	1	b	b	b	L	O

rows are yield rows which contain a negative yield amount for spinach in the appropriate week of harvest. While spinach is assumed harvested in only one week, some of the crop are harvested for multiple weeks. The next few rows allow for any spinach labor requirements to be purchased through labor purchasing activities at five dollars an hour in the week of need. Finally, land rows contain a positive 1 for each week spinach requires land from seedbed preparation to the end of harvest. The water rows allow water to be supplied to the spinach production activities through the water buy activities.

The next few columns represent the labor hire activities. The objective value is the negative price of labor ($5 per hour). In the week that labor is purchased the positive price of labor is entered in the cash flow rows. Also, a negative 1 is entered in the labor supply row for the week that labor is supplied by the activity.

Selling activities contain a positive price for spinach that contributes to the objective function. Prices for the vegetable crops vary during the harvest period. In the cash flow rows, for the week the activity is selling spinach, there is a value equal to the week's spinach price which contributes to cash flow. Furthermore, a positive 1 occurs in the spinach yield row for the week. It should be noted that farmers are assumed to receive income from product sales the week of harvest.

Transfer cash flow activities transfer cash flow from week to week. Positive cash flow transfer has been designed to create interest income from week to week approximately equal to the return on typical passbook savings (5.2 percent per annum).

The operating capital borrowing activities provide means to borrow operating capital. The objective value is the negative interest charge depending on how long the operating capital is borrowed. Operating capital may be borrowed in four week periods. In the capital rows a positive 1 represents the borrowing of one dollar.

The last columns are the irrigation development activities. These activities build the irrigation systems and transfer water to the water row. An acre inch of water is provided to the crops through the water buy activities.

The final two columns are the row type column which indicates the constraint type and the right-hand-side (RHS) column which contains resource levels for the model. In the RHS column, land is limited to the amounts specified for each scenario, and total operating capital borrowed is limited to $300 per acre.

Resource Assumptions and Input Data Requirements

Land and basic farm equipment are assumed owned. The machinery complement assumed in the model includes a tractor, herbicide sprayer, insecticide sprayer, transplanter, disc, cultivator, trailer, rototiller, cultibedder, planter, plow and spike harrow. Except for the transplanter and the cultibedder, this equipment is available on many farms. Other machinery available can be modified to do the job of the cultibedder. A 2-row transplanter can be bought for around $1,000 if needed.

Many horticultural crop varieties are well adapted to the climatic and agronomic conditions of southeastern Oklahoma. Information about the crop mixes considered and the production practices for the individual crops was obtained from Oklahoma State University horticulturists (Motes, 1985). The most important criteria for selecting varieties is whether or not the variety is one accepted by the buyer (Tilley and Schatzer, 1985).

Production data make up a large portion of the data requirements. Production data including fertilizer, pesticides, seed, harvesting cost, and marketing and grading costs used in this study are based on enterprise budgets developed by Schatzer, Wickwire, Tilley and Motes (1986).

The enterprise budget information is used to develop the vegetable activities in the model. As discussed in the description of the model tableau, vegetable activities yield a quantity which is sold by selling activities and require labor, water and operating capital which is supplied by purchasing activities. Since it is assumed that the aggregate non-irrigation machinery fixed costs do not change, these values are not included in the model, except for irrigation. Summaries of the coefficients of the production activities are provided in Table 2.

Product prices for each possible marketing week are determined by averaging corresponding weekly prices that occurred at the Dallas Wholesale Produce Market for the years 1978 through 1983. It is assumed that producers would receive Dallas Wholesale prices, less a fifteen percent brokerage fee. These weekly prices are provided in Table 3. Southern peas price is assumed to be $8.00 per bushel for all weeks due to lack of consistent price at Dallas.

Crop yields used in this study are based on research data and discussions with established producers in the state. The per acre yields are reported in Table 2. These yields may vary depending on 1) management skills of operators; 2) planting dates; 3) harvesting dates; and 4) growing conditions and cultural practices. Beginning growers should not expect these yields or prices consistently for their crops until they gain experience in the production and marketing of horticultural crops.

An unlimited quantity of labor is assumed available at a price of five dollars per hour. All labor is assumed hired and perfect in mobility. If all labor is provided by the farm family, the labor charge is an opportunity cost reflecting the wage the individual could receive in alternative employment.

It is assumed the producer has no operating capital at the beginning of the year but may borrow up to $300 of operating capital per acre at an annual interest rate of fifteen percent. In many instances, after the first vegetable crop harvest, the weekly operating capital requirements can be met by revenues generated from product sales.

For the individual producer scenarios and for the irrigation district scenarios, an annual interest rate of 12 percent and a payback period of 7 years was assumed for calculating capital costs for the complete irrigation system (structure, pump,

TABLE 2. YIELD, LABOR AND WATER REQUIREMENTS AND VARIABLE COST EXCLUDING LABOR, IRRIGATION, AND INTEREST COST FOR EACH CROP ON A PER ACRE BASIS.

Crop	Yield	Machinery Labor	Hand Labor	Harvest Labor	Irrigation Water	Variable[a] Cost
		(hours)	(hours)	(hours)	(ac.-ins.)	(dollars)
Snap Beans (bushels)	120	9.7	4	60.0	4.0	435.00
Broccoli, fall seeded (crates)	400	10.8	6	120.0	8.5	1,271.91
Broccoli, fall transplant (crates)	375	12.2	18	112.5	4.5	1,455.25
Broccoli, spring seeded (crates)	375	11.0	6	112.5	6.5	1,251.37
Broccoli, spring transplant (crates)	350	12.8	18	105.0	5.5	1,421.98
Cantaloupe (crates)	250	11.3	8	100.0	8.5	654.36
Cucumber (cartons)	300	10.2	12	90.0	8.0	763.17
Okra (cartons)	500	12.6	6	300.0	8.5	891.72
Peppers, Bell (cartons)	300	15.9	27	120.0	6.5	1,339.91
Peas, Southern (bushels)	125	11.6	8	63.0	7.0	284.10
Spinach, spring (bushels)	400	8.4	0	200.0	3.0	1,059.94
Squash, yellow summer (cartons)	500	10.2	24	200.0	7.0	1,258.31
Sweet Corn (crates)	180	10.5	4	30.0	7.0	476.75
Sweet Potatoes (bushels)	300	6.2	41	90.0	12.0	1,245.19
Tomatoes (lugs)	700	21.1	247	200.0	9.0	1,865.91
Watermelon (pounds)	14,000	10.8	13	28.0	8.5	228.76

[a] Variable cost excludes the cost of labor, irrigation and interest.

TABLE 3. AVERAGE WEEKLY PRODUCE PRICES FOR SELECTED VEGETABLE ENTERPRISES

Week	Spring Spinach	Spring Broccoli	Summer Squash	Snap Beans	Sweet Corn	Cucumber
	$/bu.	$/cart.	$/cart.	$/bu.	$/cart.	$/cart.
14	6.87					
15	7.34					
16	7.01					
17	7.72	7.76				
18	7.01	7.40				
19	7.65	7.40	4.57			
20	7.91	7.01	4.30			
21	8.01	6.65	4.06			
22	8.16	6.85	3.90	10.04		
23	7.79	7.29	3.59	9.48	6.16	9.56
24	7.93	7.46	3.56	9.60	6.77	10.12
25	7.97		4.06	10.41	7.62	9.10
26			4.34	10.16	8.01	9.38
27			5.08	9.89	8.08	9.32
28			5.01	10.38	7.39	9.30
29			4.68	10.40	7.34	10.17
30			4.80		6.57	8.61
31			4.60		6.32	7.79
32			4.41			7.68
33			4.73			6.98
34			4.82			6.70
35			4.92			7.08
36			5.33			8.53
37			5.94			8.20
38			5.21			8.19
39			5.56			8.36
40			4.29			9.32
41			4.62			8.64
42			5.42			8.02
43			5.14			7.85
44						7.35
45						
46						
47						
48						

TABLE 3. (continued)

Week	Okra	Bell Peppers	Tomatoes	Canta loupe	Water melon	Sweet Potaotes	Fall Broccoli
	$/cart.	$/cart.	/lugs	$/cart	$/cwt.	$/bu.	$/cart
14							
15							
16							
17							
18							
19							
20							
21							
22							
23							
24	5.88	10.29					
25	5.92	10.38	9.44				
26	5.95	10.72	8.86				
27	5.77	11.32	8.60				
28	5.95	9.97	7.16	7.46			
29	6.09	9.77	6.49	6.89	5.53		
30	5.88	944	7.31	6.43	5.38		
31	5.59	9.93	7.30	6.60	4.74		
32	4.73	9.74	6.59	6.61	4.89		
33	5.09	9.41	6.50	6.55	4.57		
34	4.72	8.25		6.04	3.97		
35	4.71			6.32	3.68		
36	4.85			6.67	3.68		
37	4.79			6.70	3.76	8.50	
38	4.96			6.87	3.89	8.36	
39	5.21			6.89		8.11	
40	5.17			6.90		7.83	
41	5.46			7.28		7.74	
42	5.53			7.23		7.52	7.08
43	5.56					7.49	7.24
44							6.96
45							6.91
46							7.26
47							6.64
48							6.49

motor, and distribution system). For the bond fund scenarios, the program interest rate of 8.94 percent was used with an assumed payback period of twenty five years -- the maximum eligible under the program.

It should be noted that costs of forming and administering a district are not considered. The economic costs of such activities for a minimal size district are likely to be negligible. However, the psychic costs to an individual member of such endeavors may be substantial due to the necessity for close cooperation among members. Therefore, these costs should be carefully considered before the district is formed.

POND CONSTRUCTION COST CALCULATIONS

Technical information used to estimate the cost and physical parameters for the ponds appropriate for the areas irrigated, was obtained from Oklahoma State Water Resource Specialists with the Soil Conservation Service (SCS), United States Department of Agriculture. Cost information (costs of soil moved, cover establishment, necessary pipe requirements, etc.) for developing such structures was obtained from the Oklahoma State Office of the Agricultural Stabilization and Conservation Service, United States Department of Agriculture.

To obtain the construction costs of the ponds, the total number of yards of soil moved for a desired acre inch capacity was calculated. This value is multiplied by the expected cost per yard for soil moved ($0.70). An average depth of eight feet was assumed. A minimum depth of six feet was assumed to guarantee water to support a fish population that could be used for recreation purposes and for irrigation through further draw down in extremely dry years. Total area (structure surface area plus a thirty foot spoilage area) was then calculated. By subtracting the structure surface area from the total area value, the area of spoilage requiring cover was calculated. This spoilage area times the price per acre of cover ($116), equals the total cover cost. Also, the perimeter of the total area was calculated. By multiplying the perimeter value by the price of fencing per foot, ($0.46), a total fencing cost was obtained. The summation of the total cost of soil moved, fence cost, cover cost, and a drainage pipe cost of $576, yields a total cost of construction for a structure. The pond construction cost curve is provided in Figure 1. Maintenance cost for the cover, structure, and fence were assumed negligible after the establishment year.

Figure 2 depicts the layout of the irrigation system for the individual producer scenario. For this scenario, 200 feet of above ground main line was assumed to run from the pond to the vegetable plot. For the furrow systems, the main line leading from the pond connects to a length of gated lateral pipe running the length of the plot from which water is applied directly to the crops. For the sprinkler scenarios, a segment of lateral pipe equipped with sprinklers running perpendicular to the main line applies water to the crops as it is moved over the plot.

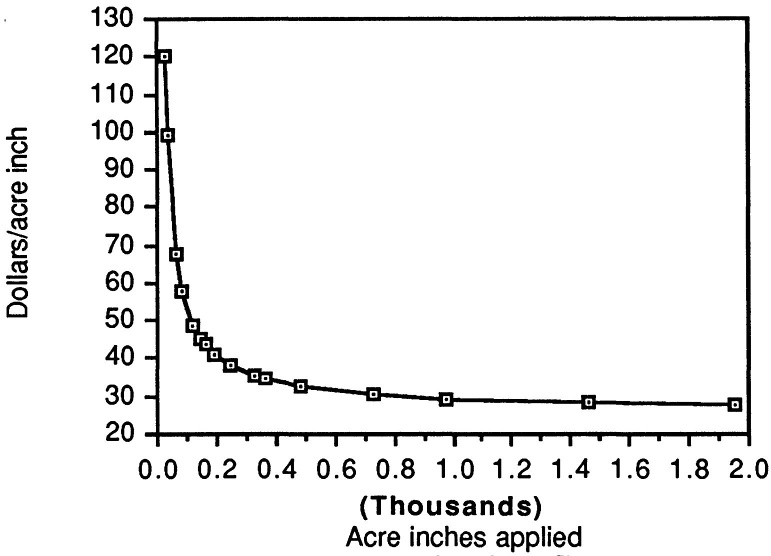

Figure 1. Calculated Pond Construction Cost Curve.

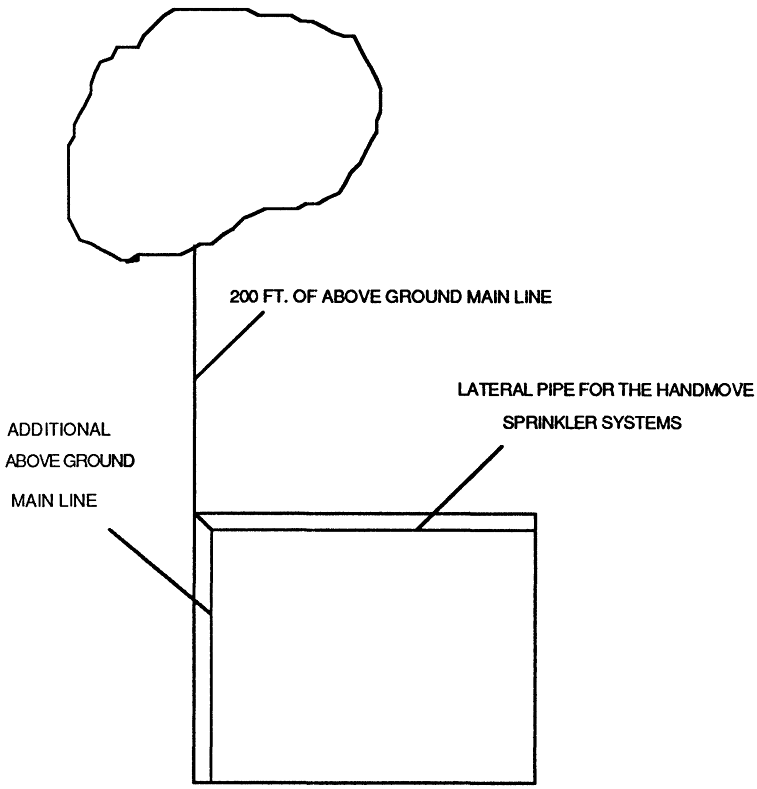

Figure 2. Assumed Individual Producer Irrigation System Layout.

Figure 3 depicts the layout for the hypothesized irrigation district. Individual plots are supplied water through a 5,280 foot below ground main line leading from a central pond. A 200 foot lengthof above ground main line delivers the water from the main line to the respective plots. In the irrigation district scenarios, the layouts on the respective plots for both sprinkler and furrow systems are identical to those in the individual producer scenarios. It should be noted that the distances assumed are simply for purpose of analysis and the distances will, in reality, vary depending on individual cases.

Non-structure related irrigation capital and operating costs were estimated by using the O.S.U. Irrigation Cost Generator (Kletke, Harris and Mapp, 1978). The Irrigation Cost Generator is a computer program which calculates cost information, both fixed and variable, on a per acre-inch and per acre basis. Estimates can be made with various assumptions regarding the irrigation well, fuel source, distribution system, and water requirements. Many, if not most, irrigation situations can be simulated by specifying key variables accordingly. Data taken from the Irrigation Cost Generator output include labor requirements, fixed costs, and variable costs for the pump, motor, and the distribution system. Application efficiency, the ratio of the amount of water stored in the crop root zone through irrigation to the amount of water applied, is assumed to be 80 percent and 60 percent for handmove sprinkler and furrow irrigation, respectively (Wade, 1986).

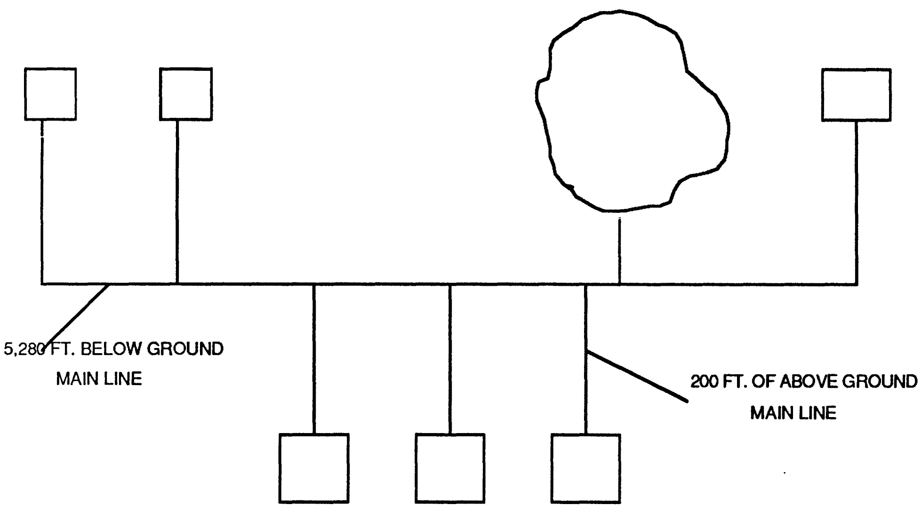

Figure 3. Assumed Irrigation District Layout.

RESULTS AND COMPARISON OF SCENARIOS

The compilation of data from sources discussed allows identification of an objective function, resource bases, activity limits, and product prices for alternative southeastern Oklahoma horticultural crop production scenarios. Using the linear programming Mathematical Programming Solutions Extended (MPSX) algorithm, returns to risk, land, management, and non-irrigation related capital investment cost for machinery and improvements were maximized.

Estimates of net returns, ending cash flow, labor requirements, and irrigation investment cost requirements, were used to evaluate the alternative scenarios. Ending cash flow represents the total annual cash available at the end of the year after paying all operating costs (including all labor at $5 per hour and all borrowed operating capital at 15 percent interest) and the principal and interest payment on the complete irrigation system. After seven years for the individual producer scenarios and the irrigation district scenarios without bond funds and after twenty-five years for the irrigation district scenarios with bond funds, the ending cash flow would increase by the amount of the principal and interest payments. Net returns are a return to risk, land, management, and other non-irrigation related capital investments such as machinery and improvements. The difference between the ending cash flow and the net returns represents the difference between the annual fixed cost of investing in the irrigation system and the annual principal and interest payment required to finance 100 percent of the irrigation system investment cost. Estimated investment costs are for the complete irrigation system (structure, pump, motor, and distribution system).

The ending cash flow estimate is recommended as a more accurate measure of net cash benefit accruing to a producer than is the net returns estimate. With the everyday cash inflows and outflows incorporated into the ending cash flow, the ending cash flow value more accurately depicts the "real life" cash income situation the producer is facing and therefore his financial situation. As mentioned earlier, labor is assumed paid. Thus if part of the labor is supplied by the family, the savings in labor costs would increase the ending cash flow amount. New commercial horticultural crop producers should expect their revenues to fall somewhat short of the predicted values in this study. These estimates assume no risk and adequate resources including high level management for the optimal production levels.

For all situations, the profit maximizing crop mix was found to be a triple crop combination of spring spinach, cucumbers, and seeded fall broccoli.

Scenario One

Scenario one addresses the economics of irrigated horticultural crop production for an individual horticultural crop producer involved in no special institutional arrangements. The producer pays all costs of the complete irrigation system. Estimates were made for the four different acreage assumptions, and the two different irrigation systems.

For the one acre sprinkler system, net return was $1,620 and cash flow was $697. To provide the 2.03 acre feet of water required for irrigation, it would be necessary to construct a pond with approximately 1.53 acres of surface area. Average ending cash flow and net return per acre of total land used (in vegetables and the irrigation structure) was $211 and $491 respectively. The total investment cost of the complete irrigation system would be $10,768.

Results for the other alternatives in scenario one are provided in Tables 4 and 5. As the number of acres planted to vegetables increases, the returns per acre of total land used increases. Therefore, even for the small individual producer there are substantial economies of size associated with the building of surface water irrigation structures. Returns for sprinkler irrigation are higher than for furrow irrigation reflecting the decreased efficiency of furrow irrigation.

Scenario Two

Scenario two was designed to estimate the potential economic impact on an individual producer of the formation of a six member irrigation district. Individual producers would each provide only their respective share, (1/6), of the total cost of the complete irrigation system. The four acreages of vegetables are again examined, consequently the total acreages being served by the irrigation district would be 6, 15, 30, and 60 acres, respectively. Estimates are again made for furrow and sprinkler technologies.

For the one acre sprinkler system, net return was estimated to be $2,014 and ending cash flow was $1,481. The water collection structure required to provide the 12.19 acre feet of water needed by the district to support the enterprises would cover 9.16 acres of surface area. The individual producer's share of the investment cost of the complete irrigation system would be $6,681.

Results for the other alternatives in scenario two are provided in Tables 6 and 7. Again as the number of acres planted to vegetables increases, the return per acre of total land used increases. Also returns for sprinkler irrigation are higher than furrow.

Comparison of Scenario One to Scenario Two

Scenario one addresses the individual horticultural crop producer, faced with individual cost curves. Scenario two represents the impacts on an individual producer of joining an irrigation district.

The development of an irrigation district would indeed increase the net return and cash flow of the producer both on a per acre of vegetables and per acre of total

TABLE 4. ESTIMATED ANNUAL NET RETURNS AND NET CASH FLOW FOR AN INDIVIDUAL PRODUCER WITH OWN IRRIGATION WATER STRUCTURE

IRRIGATION SYSTEM	ACRES IN VEGETABLES	TOTAL[a] ACRES USED	TOTAL ANNUAL NET RETURNS	TOTAL ANNUAL NET CASH FLOW	ANNUAL NET RETURN PER TOTAL ACRE USED	ANNUAL NET CASH FLOW PER TOTAL ACRE USED
	acres	[dollars)	(dollars]	(dollars]	[dollars]	(dollars)
Sprinkler	1	3.30	1,620	697	491	211
Sprinkler	2.5	7.49	5,852	4,691	781	626
Sprinkler	5	14.26	12,894	11,498	904	806
Sprinkler	10	27.54	27,079	25,272	983	918
Furrow	1	3.91	1,710	745	438	191
Furrow	2.5	8.93	5,838	4,698	654	526
Furrow	5	17.04	12,772	11,376	750	668
Furrow	10	32.97	26,623	24,753	807	751

[a] Total acres used includes the area in vegetables, surface area of pond and he spoilage area around the pond.

TABLE 5. ESTIMATED INVESTMENT COST, SURFACE AREA, AND CAPACITY FOR THE RESPECTIVE ACREAGES AND IRRIGATION SYSTEMS FOR INDIVIDUAL PRODUCER WITH OWN IRRIGATION WATER STRUCTURE

IRRIGATION SYSTEM	ACRES IN VEGETABLES	INVESTMENT COST	SURFACE AREA	STORAGE CAPACITY	USEABLE CAPACITY
	(dollars)	(dollars)	(dollars)	(acre/feet)	(acre/feet)
Sprinkler	1	10,768	1.53	12.21	2.03
Sprinkler	2.5	12,371	3.82	30.54	5.08
Sprinkler	5	15,084	7.63	61.07	110.16
Sprinkler	10	19,781	15.27	122.17	20.31
Furrow	1	9,915	2.04	16.29	2.71
Furrow	2.5	11,819	5.09	40.72	6.77
Furrow	5	14,600	10.18	81.44	13.54
Furrow	10	19,684	20.36	162.90	27.08

TABLE 6. ESTIMATED NET RETURNS AND ENDING CASH FLOW FOR AN INDIVIDUAL PRODUCER THAT PARTICIPATES IN A SIX- MEMBER IRRIGATION DISTRICT

IRRIGATION SYSTEM	ACRES IN VEGETABLES	TOTAL[a] ACRES USED	TOTAL ANNUAL NET RE-TURNS	TOTAL ANNUAL NET CASH FLOW	ANNUAL NET RETURN PER TOTAL ACRE USED	ANNUAL NET CASH FLOW PER TOTAL ACRE USED
	acres	[dollars)	(dollars)	(dollars)	(dollars)	[dollars]
Sprinkler	1	2.82	2,014	1,481	714	525
Sprinkler	2.5	6.78	6,248	5,644	922	832
Sprinkler	5	13.28	13,517	12,874	1,018	1,046
Sprinkler	10	26.18	28,080	27,374	1,073	1,046
Furrow	1	3.38	2,194	1,773	649	525
Furrow	2.5	8.12	6,795	6,059	837	746
Furrow	5	15.92	13,667	13,202	858	829
Furrow	10	31.41	27,980	27,464	891	874

[a] Total acres used includes the area in vegetables, surface area of pond and the spoilage area around the pond.

TABLE 7. ESTIMATED INVESTMENT COST, FOR AN INDIVIDUAL PRODUCER THAT PARTICIPATES IN A SIX-MEMBER IRRIGATION DISTRICT AND THE DISTRICT'S REQUIRED SURFACE AREA AND CAPACITY FOR THE RESPECTIVE ACREAGES AND IRRIGATION SYSTEMS

IRRIGATION SYSTEM	ACRES IN VEGETABLES	INVESTMENT COST	SURFACE AREA	STORAGE CAPACITY	USEABLE CAPACITY
	(dollars)	(dollars)	(dollars)	(acre/feet)	(acre/feet)
Sprinkler	1	6,681	9.16	73.29	12.19
Sprinkler	2.5	9,497	22.91	183.25	30.47
Sprinkler	5	11,646	45.81	361.47	40.63
Sprinkler	10	15,711	91.63	733.01	121.88
Furrow	1	5,906	12.21	97.72	16.25
Furrow	2.5	7,419	30.54	244.32	40.63
Furrow	5	9,648	61.08	488.65	81.25
Furrow	10	13,950	122.17	977.38	162.50

land area used. Also, irrigation districts can serve to substantially reduce individual producer's investment costs.

For the one acre sprinkler operation, the development of irrigation districts accounted for a $394 increase in net returns, a $784 increase in cash flow, and most importantly a $4,087 decrease in the investment capital required by the producer as compared to the individual producer scenario. As the number of acres planted to vegetables increased, the cost savings increased on an aggregate basis but decreased on a per acre of land used basis.

Scenario Three

Scenario three is designed to represent the potential economic benefit accruing to an irrigation district member from the available low interest, state guaranteed loan funds.

Net return for the one acre sprinkler system was estimated to be $2,014 and ending cash flow was estimated at $2,279. The net returns are identical to scenario two but ending cash flow increases due to the lower interest rate and increased payment period on the investment cost of the irrigation system. Structure size and total investment cost required for scenario three was identical to scenario two. Net return and cash flow results for scenario three are provided in Table 8.

Comparison of Scenario Two to Scenario Three

Comparison of results from scenarios two and three indicates the potential economic benefit to an irrigation district member from using the available low interest, state guaranteed loan funds. There are positive effects on the representative producers' ending cash flow. No change in the producers' net returns or operating capital needs are indicated between the two scenarios.

For the one acre sprinkler operation, the use of the low interest, state guaranteed bond funds results in an increase cash flow of $798 above the cash flow for the irrigation district without the low interest loan. As the number of acres planted to vegetables increases, the total difference in cash flow increases but the per acre of land use difference decreases.

Comparison of All Three Scenarios

Figure 4 provides a graphical comparison of the per total acre cash flow for the three scenarios. Two conclusions can be drawn from the figure. First, the increases in cash flow generated by the development of irrigation districts are substantial. Even greater increases are experienced when the low interest bond

TABLE 8. ESTIMATED NET RETURNS AND ENDING CASH FLOW FOR AN INDIVIDUAL PRODUCER THAT PARTICIPATES IN A SIX-MEMBER IRRIGATION DISTRICT THAT USES THE LOW INTEREST, STATE GUARANTEED LOAN FUNDS..

IRRIGATION SYSTEM	ACRES IN VEGETABLES	TOTAL[a] ACRES USED	TOTAL ANNUAL NET RETURNS	TOTAL ANNUAL NET CASH FLOW	ANNUAL NET RETURN PER TOTAL ACRE USED	ANNUAL NET CASH FLOW PER TOTAL ACRE USED
	acres	(dollars)	(dollars)	(dollars)	(dollars)	[dollars[
Sprinkler	1	2.82	2,014	2,279	714	808
Sprinkler	2.5	6.78	6,248	6,596	922	973
Sprinkler	5	13.28	13,517	13,925	1,018	1,049
Sprinkler	10	26.18	28,080	28,601	1,073	1,092
Furrow	1	3.38	2,194	2,387	649	706
Furrow	2.5	8.12	6,795	6,714	837	827
Furrow	5	15.92	13,667	13,916	858	874
Furrow	10	31.41	27,980	28,284	891	900

[a] Total acres used includes the area in vegetables, surface area of pond and the spoilage area around the pond.

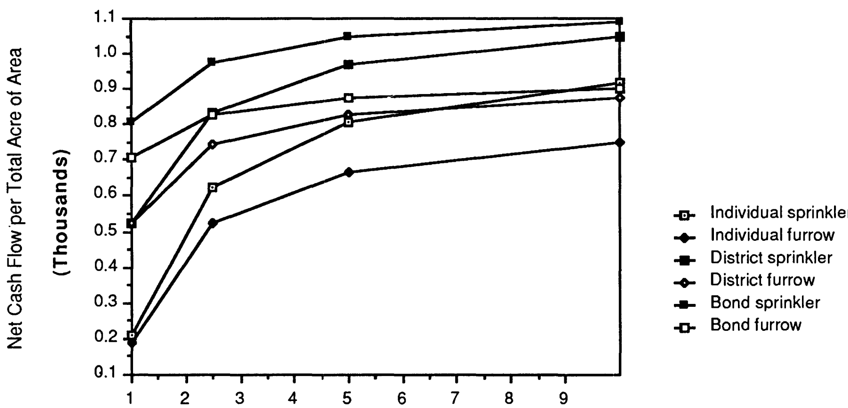

Figure 4. Net Cash Flow per Total Acre of Area Used for Each Scenario.

funds are used, although the size of the increase declines as the number of acres increased. Second, the increase in size has a greater effect on the individual producer scenario than the district scenario. This result supports the economics of size hypothesis stated earlier. There are substantial economies of size up to about 500 acre inches of water applied. After this point, the costs decline very slowly.

CONCLUSIONS

Because of the reliance of southeastern Oklahoma on agriculture, it is conceivable that improvements in the agriculture sector could lead to substantial economic development for the area. For the horticultural crop industry to be commercially successful, adequate marketing skills, labor, production information, and irrigation water must be present.

Using production economics and linear programming theory, this study deals with the task of providing sufficient water for irrigation application on vegetable crops, and with the profitability of such vegetable production. A separable programming model was used to determine the optimal horticultural crop product mix, net returns, ending cash flow and operating capital for various scenarios. A triple crop combination of spring spinach, summer cucumbers, and fall broccoli comprised the profit maximizing product mix. This crop mix is easily adapted to southeastern Oklahoma and fits relatively well with the production capabilities of the areas' producers.

Scenario one addressed the economics of an individual producer faced with the costs of developing an individually owned surface water collection structure and the associated irrigation system. Scenario two was developed on the assumption that the representative producer in scenario one joined a six member irrigation district in an effort to reduce individual investment costs for the collection structure and associated irrigation system.

Over all sizes and both irrigation technologies, there are substantial increases in ending cash flows and net returns provided to a producer by joining a six member irrigation district. The cost per irrigator of the structures is less for the irrigation districts than for individual producers due to the economics of size in the construction of the collection structure and the reduced share of the investment cost for the system.

Scenario three addressed the potential economic impacts to potential irrigation district members from the district receiving low interest state guaranteed funds for water development. The ending cash flow figures for this scenario are greater than comparable figures for scenario two by the amount of interest saved due to the lower interest rate used for the bond funds and the substantially longer payback period available in the state program. However, the scenario two cash flows will increase by the amount of the interest and principal payments after seven years while it would be twenty-five years before such increased occurred for scenario three. Therefore, for the larger vegetables acreages the producer would probably be better off without the bond funds at the interest differential used.

It was determined from the results of this study, producers benefit from using more efficient technology such as handmove sprinklers, which have a higher application efficiency than furrow irrigation systems. This benefit occurs even though the furrow irrigation systems have lower investment costs and labor requirements than the handmove sprinkler systems. The higher application efficiency explains why the furrow systems use more labor than the handmove sprinkler.

As expected, the per acre returns increased as acreage and pond size increased. This result is largely due to the economics of size available as the size of the pond increases.

RECOMMENDATIONS FOR FURTHER RESEARCH

A given in vegetable production is the high variability in product prices and yields from one week and/or year to the next. The sensitivity of irrigation system development to changes in the prices and yields of the optimal crop mix was not examined in this study. The results showed that irrigation system development was a profitable activity under expected prices and yields. If expected prices and/or yields change, the optimal crop mix may also change which might influence the size of pond required. Further research into the size of structures required for other crop mixes should be considered.

The analysis neglects the organization and legal aspects of the formation of the irrigation districts. Numerous questions arise pertaining to the legal and organizational aspects of the district formation and operation. Additional financial questions exist including management of districts' funds, insurance, and liabilities.

Other important questions this study does not address include the placement of water district structures, compensation to producers whose lands are used for structures, and rights and responsibilities of individual district members. Additional research is necessary to address these important aspects of irrigation district formation to aid potential district members in management decisions.

The importance of marketing to vegetable producers cannot be overemphasized. Research should continue to address marketing issues including potential markets, and desired crops.

Available labor in southeastern Oklahoma, especially for harvesting, looms as a possible impediment to the success of a horticultural crop industry. For one acre of vegetable production with sprinkler and furrow irrigation the maximum peak labor requirements are 476 and 477 hours respectively. Insufficient labor for harvesting will result in crops being planted, maintained, and/or harvested at non-optimal times which can lead to reduced yields, quality or prices. These problems can lead directly to reduced profits and perhaps, if the problems persist, growers could lose buyers. Research should be conducted to address labor issues such as hiring schemes, length of labor procurement, and the effects on profits of insufficient labor. This concern is especially true for crops with a short, labor intensive, harvest period, where large numbers of laborers are required to effectively harvest crops to prevent a drop in product quality or price. Though low-income, small scale producers with adequate family labor can perhaps escape this labor shortage on a small acreage, larger commercial operations will become increasingly dependent on migrant labor as the sizes of their operations increase.

An important aspect of the production of agricultural commodities is risk. Research needs to be conducted which addresses the potential price and yield risk facing Oklahoma vegetable producers. Information about drops in yields, prices, and/or quality because of planting date delays would be beneficial to producers.

The high returns estimated for handmove sprinkler alternatives considered in this study indicate that though technology is initially more expensive, long run benefits may make more efficient technology desirable. Other advanced irrigation systems should be investigated.

There exists a significant opportunity to develop horticultural crop markets in which southeastern Oklahoma has a definite advantage in transportation over the established horticultural crop states such as California and Florida. Climatic and agronomic factors clearly indicate that production possibilities are excellent, and current marketing arrangements are proving productive and profitable. If adequate irrigation water and labor can be made available, southeastern Oklahoma could be a source of high quality, fresh produce for many major cities in the Midwest. Such development would provide a generous economic boost to the area's poor and unemployed.

LITERATURE CITED

Dale, Jeffrey F., Raymond Joe Schatzer and James R. Nelson. "The Economics of Irrigated Specialty Crop Production in Southeastern Oklahoma with Special Consideration for a Public Cost-Sharing Program." P-2103 of the Oklahoma Agricultural Experiment Station presented at the Mississippi Water Resources Conference, Jackson, Mississippi, February 1986.

Kletke, Darrel D., Thomas R. Harris, and Harry P. Mapp. Irrigation Cost Program Users Reference Manual, Department of Agricultural Economics, Oklahoma Agricultural Experiment Station, Oklahoma State University, Stillwater, Oklahoma, Research Report P-770, May, 1978.

Motes, James E. Personal Interview. Stillwater, Oklahoma, March, 1985.

Oklahoma Geological Survey. Geohydrology of the Antlers Aquifer (Cretaceous), Southeastern Oklahoma, Circular 81. Norman, University of Oklahoma Printing Services, 1981.

Oklahoma Water Resources Board. Mimeographed document describing Series 1985. $50 Million Revenue Bond Issue, Oklahoma City, 1986.

Schatzer, Raymond J., Michael G. Wickwire, Daniel S. Tilley and James E. Motes. "Costs and Returns for Selected Fresh Market Vegetables in Oklahoma for Small Scale Producers". Research Report P-875, Agricultural Experiment Station, Oklahoma State University, Stillwater, April, 1986.

Tilley, Daniel S. and Raymond J. Schatzer. "Should I Commercially Grow Vegetables and/or Fruits?" Stillwater: Oklahoma State University Cooperative Extension Service OSU Extension Facts No. 165, August, 1985.

Wade, James C., "Efficiency and Optimization in Irrigation Analysis." Energy and Water Management in Western Irrigated Agriculture. Ed. Norman K. Whittlesey. Boulder: Westview Press Inc., 1986, pp. 73-100.

Wickwire, Michael C. "Supplemental Vegetable Crop Mixes for A Cow-Calf and Grain Producer In Bryan and Atoka Counties In Oklahoma," unpublished Master's Thesis, Department of Agricultural Economics, Oklahoma State University, Stillwater, Oklahoma, July 1985.

OKLAHOMA
AGRICULTURAL EXPERIMENT STATION
System Covers the State

★ **Main Station** — ***Stillwater and Lake Carl Blackwell***

1. **Panhandle Research Station** — ***Goodwell***
2. **Southern Great Plains Field Station** — ***Woodward***
3. **Sandyland Research Station** — ***Mangum***
4. **Irrigation Research Station** — ***Altus***
5. **Southwest Agronomy Research Station** — ***Tipton***
6. **Caddo Research Station** — ***Ft. Cobb***
7. **North Central Research Station** — ***Lahoma***
8. **Forage and Livestock Research Laboratory** — ***El Reno***
9. **South Central Research Station** — ***Chickasha***
10. **Agronomy Research Station** — ***Perkins***
    Fruit Research Station — ***Perkins***
11. **Pecan Research Station** — ***Sparks***
12. **Pawhuska Research Station** — ***Pawhuska***
13. **Vegetable Research Station** — ***Bixby***
14. **Eastern Research Station** — ***Haskell***
15. **Kiamichi Forestry Research Station** — ***Idabel***
16. **Wes Watkins Agricultural Research and Extension Center** — ***Lane***

CENTENNIAL
1890 • 1990

Reports of Oklahoma Agricultural Experiment Station serve people of all ages, socio-economic levels, race, color, sex, religion and national origin. This publication is printed and issued by Oklahoma State University as authorized by the Dean of the Division of Agriculture and has been prepared and distributed at a cost of $641.06 for 775 copies. AI-7051 1287 TD