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Crop-Water Production Functions

Economic Implications for Colorado

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ABSTRACT

Crop-water production functions are estimated for corn, soybeans, and sugar beets grown in Colorado with two irrigation efficiency levels. Farmers with high-cost water can conserve water and increase profits by applying profit- rather than yield-maximizing water quantities if crop prices are low. Application efficiencies have a greater effect on profits at high water costs, but a greater effect on water use at low water costs. Water supply restrictions of 10 percent or less have a small effect on farm profits. Farmers should maintain full acreage in production and reduce water applications per acre for maximum profits under water supply restrictions of 20 percent or less.

Keywords: Crop response, irrigation economics, Colorado, soil-water-plant relationships.

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INTRODUCTION

Over 85 percent of all water consumed in Colorado is for 3 million acres of irrigated agriculture. Although water is plentiful for parts of the State, the major agricultural areas are in the semiarid east, where rainfall is usually less than 16 inches annually (Ruffner). Agriculture often competes with urban interests for limited surface water. Pumping lift depths and high energy prices can result in high pumping costs in some irrigated areas. The average lift for ground water is 270 feet in the State's southern high plains, where the water table is declining approximately 2 feet per year (Sloggett).

Crop yield response to irrigation water is very important to irrigators and planners because of the potential for increasing water costs and decreasing water supplies for agriculture in Colorado. Crop-water production functions are essential to analyzing the costs and benefits of water projects; irrigation policies, such as water restrictions and water pricing; and management techniques. This report focuses on crop-water production functions and economic implications for corn, soybeans, and sugar beets grown in eastern Colorado. These are the only crops for which adequate agronomic data are available to estimate crop-water production functions. (Soybeans are not a significant crop in Colorado at this time and sugar beet acreage has declined drastically since 1980.) This report is one in a series for key crops in many Western States where water scarcity is a problem.

This report: (1) estimates the crop-water production functions; (2) estimates the profit-maximizing levels of water, given different water and crop prices; (3) compares the profit-maximizing level of water with that suggested by yield-maximizing models and common practice; (4) estimates the effect of irrigation field and delivery efficiency on water use and shortrun profits; (5) estimates the effect of water quantity restrictions on water use and shortrun profits; (6) estimates the price elasticity of demand for water, and (7) draws farm and aggregate level policy implications.

METHODS AND DATA

Crop-water production functions are estimated from experiment station data which indicate crop yield response to varying amounts of irrigation water. These production functions are the basis for the economic analysis reported here.

Economic Theory

The estimated production functions are differentiated to obtain the marginal physical product (MPP). The value of the marginal physical product (VMP) is determined by multiplying the MPP by the price of each crop. Yield-maximizing levels of water are determined by equating the MPP of water to zero and solving for the amount of water. Profit-maximizing levels of water application are estimated by equating the VMP with the unit cost of the input, water. Profit-maximizing levels of water will be less than or equal to yield-maximizing levels of water, given a positive cost of water.

Elasticity of demand for water indicates the percentage change in the quantity of water used to grow a crop resulting from a 1-percent change in the cost of water. The elasticities of demand for water are determined in three steps. First, demand functions for water are estimated from the profit-maximizing equations. Next, the demand functions are differentiated with respect to the cost of water. Third, the elasticities are determined by multiplying the derivative of the demand functions, with respect to the unit cost of water, by the ratio of the cost of water to the profit-maximizing quantity of water at that cost.

Irrigation Efficiency

There are various measures of irrigation efficiencies. Delivery (or conveyance) efficiency is the amount of water delivered to a field, divided by the amount of water sent for delivery from the water source to the field. Application (or field) efficiency can have several slightly different definitions, but is defined here as the amount of irrigation water stored in a field's root zone for beneficial plant use, divided by the amount of water applied to the field.

Delivery efficiency changes affect the amount of water pumped or purchased by the farmer to obtain a given amount of water at the field head. Changes in delivery efficiency are reflected in water costs. If delivery efficiency doubles, the water supply necessary to deliver a given amount of water to a field is cut in half. Therefore, the effective unit cost of water is cut in half. Farm profits are affected by changes in delivery efficiency and profit-maximizing water quantities are affected by the associated changes in water costs.

Each crop-water production function is associated with an implicit application efficiency. A production function is not directly applicable to a different irrigation system with a different application efficiency. However, a production function may be adjusted for varying application efficiencies by multiplying the water coefficients of the function by the ratio of the new efficiency to the original efficiency, assuming no change in residual soil moisture.

Mathematically,

$$W = W_n \cdot Eff_n/Eff_a, \tag{1}$$

where:

W = irrigation water applied and rainfall associated with the original production function,

W_n = the new water application level associated with Eff_n,

Eff_a = the application efficiency associated with the original production function,

Eff_n = the new application efficiency.

Given a production function:

$$Y = a + bW + cW^2, \tag{2}$$

where a, b, and c are parameters,

and substituting (1) into (2):

$$Y = a + b\ (W_n\ Eff_n/Eff_a) + c\ (W_n\ Eff_n/Eff_a)^2. \tag{3}$$

The new marginal physical product, value of the marginal physical product, profit-maximizing level of water, and elasticity of water demand are then a function of the relative application efficiencies.

This economic analysis is short run and therefore assumes a fixed level of irrigation system technology. In the short run, a crop will be produced as long as a producer's gross returns equal or exceed total variable costs (TVC). Fixed costs, capital investment in different technologies, and the corresponding longrun economic analysis are beyond the scope of this report.

Agronomic Data

Agronomic data used to estimate the effect of water application levels on crop yield are from experiments conducted at the Colorado State University Agronomy Research Center located at Ft. Collins, Colorado. All crops were grown in a relatively uniform texture clay-loam soil.

The corn data were obtained from a 2-year (1974 and 1975) experiment with the crop irrigated by a line-source sprinkler system (Stewart and others). The line-source sprinkler experimental design allows two replications for each water level, but does not allow for random plots. Experiment application efficiencies are very high, usually between 90 and 100 percent. Irrigation treatments ranged from 0 to 14 inches, with varying schedules, over three growth stages. Seasonal rainfall was about 4 and 7.5 inches for 1974 and 1975 respectively.

Soybeans were grown for 3 years (1976 through 1978) utilizing the same line-source sprinkler experimental design as the corn experiments (Sutherland). Irrigation levels ranged from 0 to 16 inches, again with varying irrigations scheduled over three growth stages. Seasonal rainfall varied from about 3 to 6.3 inches.

A line-source sprinkler experimental design with four different harvest dates was used in the 1980 sugar beet experiment (Danielson, Flack, and Wright). Only half the data for one harvest date from this experiment were used. The north half of the experimental field showed signs of nitrogen deficiency, probably caused by leaching from an extra preseason irrigation. Irrigation levels varied from 0 to almost 16 inches and rainfall was about 6 inches.

Prices

Crop prices used in the analyses represent the high, medium, and low prices during the 10-year period (1972-81). Corn prices are $1.50, $3.00, and $4.50 per bushel; soybean prices are $5.00, $8.00, and $12.00 per bushel; and sugar beet prices are $.05, $.10, and $.17 per pound of sucrose.

Costs of irrigation water used in the analyses are $.50, $2.50, and $5.00 per acre inch to pump or divert, and deliver to the field head. These costs generally cover the range of likely water costs in the West and are used in most of the companion reports in this series (Ayer and Hoyt).

RESULTS AND ANALYSIS

Crop-water production functions are estimated for each crop (table 1) and shown graphically (fig. 1). These functions are based on the experiment station irrigation efficiencies and the water terms include both rainfall and gross water applied to the crops. The functions shown are considered the best, in both a statistical and economic sense, of the numerous equation forms and variable definitions investigated. (Growth stage production functions were estimated for all crops, but could not be used because of the lack of statistical significance of many growth stage variables. The growth stage production functions also tended to give

Table 1--Colorado crop-water production functions

Corn:

$$Y_c = \overset{***}{337.29} + \overset{***}{17.81W} - \overset{***}{.576W^2} - \overset{***}{11.74EVAP}$$
$$\quad (27.1) \quad (1.3) \quad (.06) \quad (.95)$$

$\bar{R}^2 = .88$ F = 118.23
n = 50

Soybeans:

$$Y_{SY} = \overset{***}{-7210.76} + \overset{***}{137.84W} - \overset{**}{5.16W^2} + \overset{***}{429.09EVAP}$$
$$\quad (928.8) \quad (20.9) \quad (1.6) \quad (52.6)$$

$\bar{R}^2 = .73$ F = 54.8
n = 60

Sugar beets:

$$Y_{SB} = \overset{***}{-3440.24} + \overset{***}{1047.79W} - \overset{***}{23.41W^2}$$
$$\quad (899.9) \quad (153.1) \quad (5.8)$$

$\bar{R}^2 = .92$ F = 131.55
n = 24

where:

Y_c = yield of corn grain in bushels per acre,

Y_{SY} = yield of soybeans in pounds per acre,

Y_{SB} = yield of sugar beet sucrose in pounds per acre,

W = irrigation water plus rainfall applied for the entire growing season in inches per acre,

EVAP = seasonal evaporation from a U.S. Weather Bureau Class A pan, in inches,

*** = coefficient is statistically significant at the 1 percent or better level,

** = coefficient is statistically significant at the 5 percent or better level.

Numbers in parentheses are the standard error of the estimate.

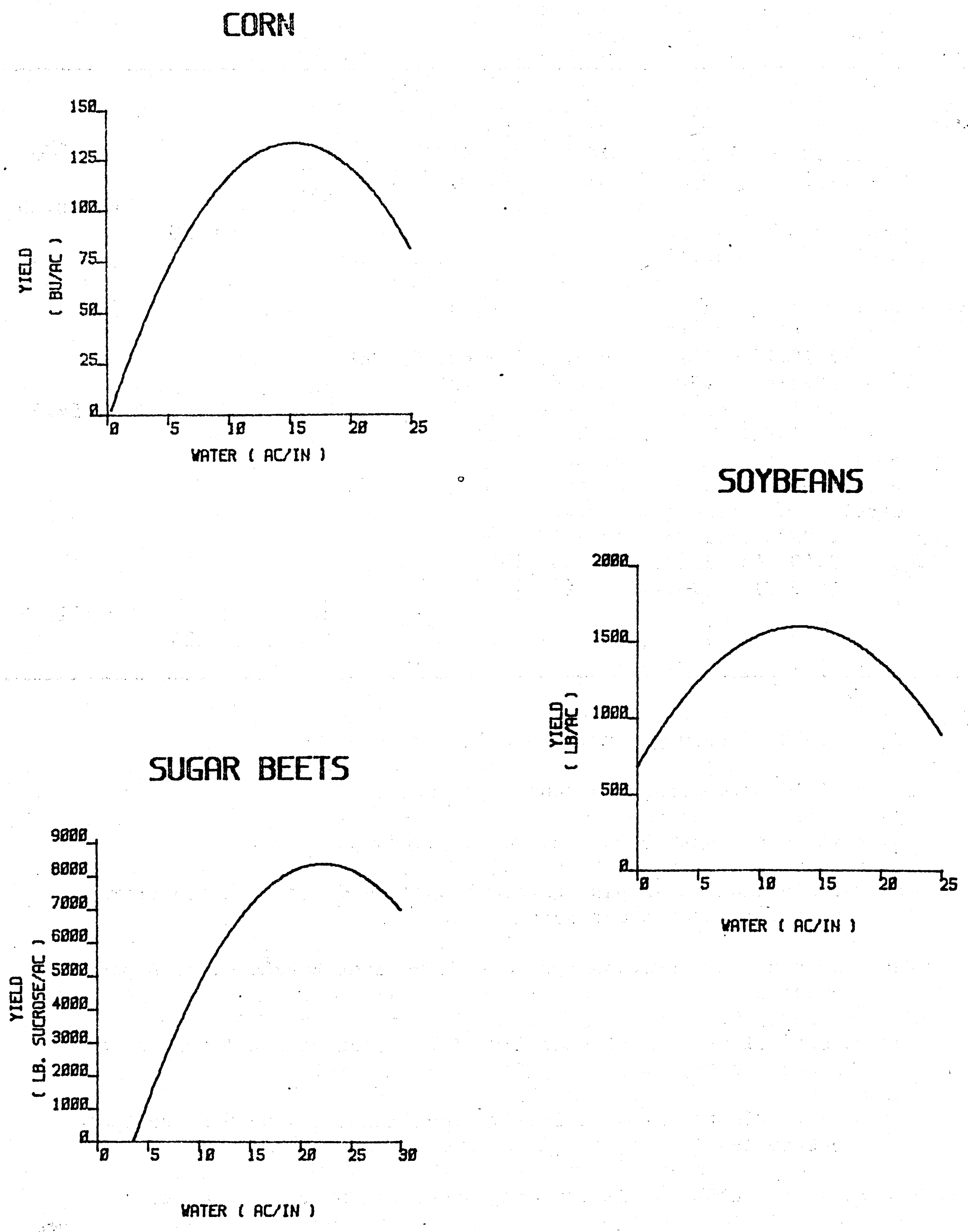

Figure 1--Crop-water production functions

unrealistic profit-maximizing water levels for some growth stages). Adjusted coefficients of determination ($\bar{R}^2$) are .73 for soybeans, .88 for corn, and .92 for sugar beets. All coefficients are statistically significant at the 5-percent level or better, and all coefficients have the expected sign. In each case, the equations show diminishing marginal returns to water applications.

Profit Maximizing Quantity of Water

Profit-maximizing quantities of irrigation water are estimated from the production functions in table 1 for both average (50 percent) and high (70 percent) irrigation application efficiencies as specified by the Soil Conservation Service. A sensitivity analysis is performed by including low, medium, and high water costs and crop prices.

Corn

Profit-maximizing water quantities (including rainfall) are shown in table 2. Water levels are not affected by changes in crop prices at low water unit costs. Medium water costs result in small water savings for high application efficiency systems, but significant (5 acre inches) savings for average application systems if crop prices are very low ($1.50 per bushel). Irrigators can increase profits by using significantly less water (5 to 11 acre inches), given high water costs, unless crop prices are high. Water savings resulting from high versus average application efficiencies vary from only 3 to 8 acre inches for corn.

Soybeans

Crop prices do not significantly affect the profit-maximizing water level for soybeans if water costs are low (table 3). However, high water costs can result in 3 to 15 acre inch savings over low-cost water. Soybeans probably would not be grown under the low crop price and high water cost combination, because the profit-maximizing water quantity is too small to assure successful plant growth. Water savings due to changing from average to high application efficiency irrigation systems are not greater than 6 acre inches.

Sugar Beets

Sugar beet profit-maximizing water quantities are not significantly affected by crop prices at low or medium water costs (table 4). Water savings are only significant (7 acre inches), given high water costs, when crop prices are low and the crop is grown with an average application efficiency irrigation system. More water (usually 10-12 acre inches) can be saved by increasing application efficiencies for sugar beets than for either corn or soybeans. This is because sugar beets initially require higher water levels than the other crops, and this difference is magnified by changing application efficiency.

Table 2--Profit-maximizing quantity of water for corn with varying water costs, crop prices, and application efficiencies, Colorado

Cost of water	Average application efficiency Crop price (dollars/bu.)			High application efficiency Crop price (dollars/bu.)		
	1.50	3.00	4.50	1.50	3.00	4.50
Dollars/ acre inch	Inches					
.50	30	30	30	22	22	22
2.50	25	28	29	19	21	21
5.00	19	25	27	16	19	20

Table 3--Profit-maximizing quantity of water for soybeans with varying water costs, crop prices, and application efficiencies, Colorado

Cost of water	Average application efficiency Crop price (dollars/bu.)			High application efficiency Crop price (dollars/bu.)		
	5.00	8.00	12.00	5.00	8.00	12.00
Dollars/ acre inch	Inches					
.50	21	22	22	15	16	16
2.50	15	18	19	12	14	14
5.00	6	12	16	8	11	13

Table 4--Profit-maximizing quantity of water for sugar beets with varying water costs, crop prices, and application efficiencies, Colorado

Cost of water	Average application efficiency Sucrose price (dollars/lb.)			High application efficiency Sucrose price (dollars/lb.)		
	.05	.10	.17	.05	.10	.17
Dollars/ acre inch	Inches					
.50	40	40	40	28	29	29
2.50	37	39	39	27	28	28
5.00	33	37	38	25	27	28

Comparison with Other Models

Profit-maximizing water applications for average application efficiencies are estimated from the production functions and compared to yield-maximizing levels, also estimated from the production functions, and with common-practice levels (table 5). The common-practice levels are assumed to be the crop's consumptive use of water, divided by the average application efficiency, 50 percent, as given by the Soil Conservation Service. Comparisons are made for three water costs, $.50, $2.50, and $5.00 per acre inch, and medium crop prices.

The yield-maximizing and common-practice water quantities are almost identical for each individual crop. Profit-maximizing water quantities are about the same as yield-maximizing and common-practice water levels for each crop at low water unit costs. At higher water unit costs, each crop's profit-maximizing water quantities behave differently. High water costs of $5.00 per acre inch result in water savings of 3, 6, and 10 acre inches respectively for sugar beets, corn, and soybeans by maximizing profits rather than following the yield-maximizing or common-practice procedure.

Anderson and Maass estimate the yield reduction for eliminating irrigations (about 5 acre inches each for farmers with average application efficiency) on corn and sugar beets. They indicate yield reductions of about 10 percent for missing the last irrigation and about 25 percent for missing the two least significant irrigations on either corn or sugar beets. The production functions indicate much lower yield reductions (about 3 percent and 9 percent, respectively) for reduced water levels of 5 and 10 acre inches on either crop.

Effects of Irrigation Delivery and Application Efficiencies on Water Use and Profits

Irrigation delivery efficiency is the quantity of water reaching the head of a field, divided by the quantity of water pumped at the wellhead or diverted to a farm for delivery to the field. The method (unlined, lined, covered ditches, or piped), condition of the conveyance system, as well as soil and climatic factors control delivery system efficiency. Delivery efficiency can have a significant impact on water use and farm profits.

A sensitivity analysis is performed for irrigation delivery efficiencies of 50 to 100 percent with two levels of irrigation application efficiency (tables 6 and 7). Substantial water losses can result from lower delivery efficiencies (usually caused by unlined or poorly maintained irrigation ditches). The delivery

Table 5--Water quantities implied by profit-maximizing, yield-maximizing and common practice models, Colorado

Cost of water	Corn			Soybeans			Sugar beets		
	Profit-max. 1/	Yield-max.	Common practice 2/	Profit-max. 1/	Yield-max.	Common practice 2/	Profit-max. 1/	Yield-max.	Common practice 2/
Dollars/ acre inch	Inches								
.50	30	31	31	22	23	22	40	40	40
2.50	28	31	31	18	23	22	39	40	40
5.00	25	31	31	12	23	22	37	40	40

1/ Based on production functions in table 1, average irrigation application efficiency and product prices of $3.00/bu. for corn, $8.00/bu. for soybeans, and $.10/lb. of sucrose for sugar beets.

2/ Based on consumptive use of crop divided by average irrigation application efficiency (Soil Conservation Service).

Table 6--Profit-maximizing quantity of irrigation water pumped[1/] or diverted with varying delivery efficiencies, average application efficiency, Colorado

Cost of water	Percent irrigation delivery efficiency								
	Corn			Soybeans			Sugar beets		
	50	75	100	50	75	100	50	75	100
Dollars/ acre inch	Inches								
.50	48	32	24	30	21	16	68	45	34
2.50	38	28	22	12	13	12	62	43	33
5.00	26	23	19	0	3	6	54	40	31

1/ Based on the production functions in table 1, medium product prices, and seasonal rainfall of 6 inches.

Table 7--Profit-maximizing quantity of irrigation water pumped[1/] or diverted with varying delivery efficiencies, high application efficiency, Colorado

Cost of water	Percent irrigation delivery efficiency								
	Corn			Soybeans			Sugar beets		
	50	75	100	50	75	100	50	75	100
Dollars/ acre inch	Inches								
.50	32	21	16	18	13	11	44	31	23
2.50	26	19	15	10	9	8	42	29	22
5.00	20	16	13	0	4	4	38	27	21

1/ Based on the production functions in table 1, medium product prices, and seasonal rainfall of 6 inches.

efficiencies also slightly affect profit-maximizing levels by increasing the effective cost of water at the field.

Delivery efficiency can significantly affect onfarm returns over total variable costs (shortrun profits). There are only small differences in shortrun profits for all crops at low water costs (tables 8 and 9). However, high water costs result in a substantial reduction in shortrun profits because delivery efficiency is reduced. Corn shortrun profits are reduced as much as 55 percent when delivery efficiencies are 50 percent instead of 100 percent. Sugar beets shortrun profits decline as much as one-third due to 50 percent versus 100 percent delivery efficiencies when water unit costs are high. Delivery efficiency has an increasing effect on shortrun profits as the unit cost of water increases.

Irrigation application efficiency is the amount of water stored in a crop's root zone for beneficial crop use, divided by the total quantity of water applied to that crop. Application efficiency may be increased by decreasing the length of run or slope of a field, or by investing in a more efficient method of application, such as gated pipe, sprinkle, or drip.

Given low water unit costs, profit-maximizing water quantities pumped are reduced by 5 to 24 acre inches when application efficiency is increased from average (about 50 percent) to high (about 70 percent) levels (tables 6 and 7). When water costs are high, 1 to 16 acre inches of water per acre are saved by switching from average to high application efficiency systems. High water costs have a greater effect on average versus high application efficiency systems' profit-maximizing water quantities.

Returns over TVC are increased by only $5 to $12 per acre by high versus average application efficiency with low-cost water, but are changed by $16 to $100 per acre at high water cost levels (tables 8 and 9). The higher application efficiency has a significant effect on profits only with high water costs.

Effect of Reductions in the Water Supply on Returns over Total Variable Costs

In periods of drought, farmers who rely on surface water supplied by irrigation districts may face a reduction in their water allocation. Farmers who pump water from dwindling aquifers may reduce their pumpage to conserve water, or have it automatically reduced by lower pump yields as the water table declines. This reduction can affect crop yields and farm profits. In this analysis, a water cost of $2.50 per acre inch and

Table 8--Returns over total variable costs 1/ with varying irrigation delivery efficiencies and average application efficiency, Colorado

Cost of water	Percent irrigation delivery efficiency								
	Corn			Soybeans			Sugar beets		
	50	75	100	50	75	100	50	75	100
Dollars/ acre inch	Dollars/acre								
.50	227	235	239	148	153	156	512	524	527
2.50	141	174	192	110	125	133	383	434	452
5.00	63	110	142	NI	110	112	238	332	368

NI = Not irrigated under this condition.

1/ Based on the production functions in table 1, medium product prices, seasonal rainfall of 6 inches, and 1980 FEDS budget.

Table 9--Returns over total variable costs 1/ with varying irrigation delivery efficiencies and high application efficiency, Colorado

Cost of water	Percent irrigation delivery efficiency								
	Corn			Soybeans			Sugar beets		
	50	75	100	50	75	100	50	75	100
Dollars/ acre inch	Dollars/acre								
.50	236	241	244	156	159	161	524	531	534
2.50	179	201	213	130	141	144	438	474	486
5.00	122	158	179	NI	126	130	340	401	428

NI = Not irrigated under this condition.

1/ Based on the production functions in table 1, medium product prices, seasonal rainfall of 6 inches, and 1980 FEDS budget.

medium crop prices are assumed. Initial water supplies are assumed adequate to provide profit-maximizing water quantities under each water cost and irrigation efficiency level. A 10-percent reduction in water supply causes a very small (almost 0 to 2 percent) reduction in shortrun farm profits (tables 10, 11, and 12). A 20-percent reduction in water supply causes a 2- to 10-percent reduction in shortrun profits.

The analysis indicates that maximum farm profits are always obtained by maintaining full acreage in production and reducing per acre water applications, with water supply reductions of 20 percent or less (tables 10, 11, and 12). For example, if a corn grower faced with a 20-percent reduction in irrigation water were to supply the full profit-maximizing water application to a reduced acreage (400 versus 500 acres), returns over TVC would be approximately $77,000. However, by spreading the water reduction over the entire 500 acres farm profits are over $89,000.

The timing of water reductions is not taken into account in the preceding analysis because the crop-water production functions are seasonal and do not include growth stages.

Water Costs and the Demand for Water

The price elasticity of demand for irrigation water applied to either corn or sugar beets is very inelastic, regardless of the price of the crop or water (table 13). Soybeans are also price inelastic, except under conditions of low product prices and high water costs, when the crop probably would not be irrigated. An inelastic demand for water indicates that there will be little change in water use in response to changes in the price of water. For example, if corn selling for $1.50 per bushel is grown with water costing $5.00 per acre inch, the elasticity of demand is -.223. That is, a 10-percent increase in the unit cost of water will reduce the demand for water by only 2.23 percent (less than 1 acre inch).

SUMMARY AND IMMPLICATIONS

This report estimates the relationship between crop yield and irrigation water for corn, soybeans, and sugar beets grown in Colorado, and provides a shortrun economic analysis based on the crop-water relationship.

The key findings are:

1. Profit-maximizing water levels are not very sensitive to product price changes at low water costs. Corn profit-maximizing water levels, at high water costs, are from 2 to 11 acre inches lower

Table 10—The effect of water supply reductions on water applications, acreage, and returns over total variable costs[1/], for a hypothetical Colorado corn farm with varying irrigation application efficiencies

Water supply reduction (percent)	Average Application Efficiency			High Application Efficiency		
	Per acre application[2/] (inches)	Acres	Returns over total variable costs (dollars)	Per acre application[2/] (inches)	Acres	Returns over total variable costs (dollars)
0	28	500	96,000	21	500	106,500
10	25	500	94,850	19	500	105,550
20	22	500	89,020	17	500	101,950

1/ Based on production functions in table 1, and medium water and crop prices.

2/ Includes 6 inches seasonal rainfall.

Table 11—The effect of water supply reductions on water applications, acreage, and returns over total variable costs[1/], for a hypothetical Colorado soybean farm with varying irrigation application efficiencies

Water supply reduction (percent)	Average Application Efficiency			High Application Efficiency		
	Per acre application[2/] (inches)	Acres	Returns over total variable costs (dollars)	Per acre Application[2/] (inches)	Acres	Returns over total variable costs (dollars)
0	18	200	26,120	14	200	28,700
10	16	200	26,040	12	200	28,480
20	14	200	25,540	11	200	28,120

1/ Based on production functions in Table 1, and medium water and crop prices.

2/ Includes 6 inches seasonal rainfall.

Table 12—The effect of water supply reductions on water applications, acreage, and returns over total variable costs[1], for a hypothetical Colorado sugar beet farm with varying irrigation application efficiencies

Water supply reduction (percent)	Average Application Efficiency			High Application Efficiency		
	Per acre application[2] (inches)	Acres	Returns over total variable costs (dollars)	Per acre application[2] (inches)	Acres	Returns over total variable costs (dollars)
0	39	160	73,950	28	160	78,580
10	35	160	72,380	25	160	76,690
20	31	160	67,420	22	160	70,980

1/ Based on production functions in table 1, and medium water and crop prices.

2/ Includes 6 inches seasonal rainfall.

Table 13—Elasticity of demand for irrigation water, corn, soybeans, and sugar beets, Colorado[1]

Cost of water	Corn dollars/bu.			Soybeans dollars/bu.			Sugar beets dollars/bu.		
	1.50	3.00	4.50	5.00	8.00	12.00	.05	.10	.17
Dollars/ acre inch									
.50	-.019	-.010	-.006	-.047	-.029	-.019	-.010	-.005	-.003
2.50	-.104	-.048	-.032	-.305	-.155	-.101	-.051	-.024	-.014
5.00	-.223	-.104	-.064	-.871	-.373	-.220	-.107	-.051	-.029

1/ Based on production functions in table 1.

than profit-maximizing levels at low water costs. Soybean growers can save up to 15 acre inches of water while sugar beet growers will save no more than 7 acre inches of water under these conditions.

2. Common-practice irrigation quantities closely approximate yield-maximizing irrigation water quantities and profit-maximizing water levels when the cost of water is low. Profit-maximizing water quantities represent a significant water savings over common-practice levels at high water costs and low crop prices.

3. Irrigation delivery efficiency has no significant effect on farm profits at low water costs, but a substantial effect on profits at high water cost levels. Application efficiencies have a greater effect on profits at high water costs, but a greater effect on water use at low water cost levels.

4. Water supply restrictions of 10 percent or less have a relatively small effect on farm shortrun profits. Farmers should maintain full acreage in production and reduce water applications per acre when faced with water supply reductions of 20 percent or less in order to maximize total farm profits.

5. The elasticity of demand for water to grow corn and sugar beets is very low. Changes in the price of water will have small effects on water use for these crops in the short run. Soybeans exhibit an inelastic demand for water except when crop prices are low and water costs are high. (The crop probably would not be irrigated under this condition.)

Farm Level Implications for Water Conservation

Water conservation can take two directions: capital investments to increase the efficiency of irrigation systems, or reductions in the amount of water applied to crops. The analysis in this report can be used to determine the potential benefits of increasing irrigation efficiency. Increasing irrigation efficiency may become economically feasible for farmers with average irrigation efficiency as the cost of water increases. Irrigators faced with more costly water and low crop price can conserve water and increase profits by applying profit- rather than yield-maximizing quantities of water.

Policy Level Implications

Because of the low price elasticity of demand for irrigation water, small increases in water costs (through increased energy prices, irrigation water taxes, etc.) will not be successful in decreasing water use in the short run. The difference between profit- and yield-maximizing water levels will increase at high water costs. For corn and soybeans, given higher water costs, water could be conserved if extension services would encourage profit- rather than yield-maximizing irrigation criteria.

There is little economic incentive to invest in water saving technologies given low water costs. As water costs increase, capital investment to increase efficiencies will become more economically viable. Policymakers can use this report to help analyze the benefits (or costs) of alternative water conservation projects or policies.

Limitations

The production functions reported are based on limited data. Growth stage production functions would be much more useful for economic analysis and water management decisions. However, statistically significant growth stage functions could not be estimated from the data. The production functions reflect experiment station yields, which are generally greater than actual farm yields.

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