Irrigation

STAFF PAPER

Projected Irrigation Water Demand and Price Elasticities for the Ouachita River Basin

by

Mike Tessaro
Larry Childress
Mark Cochran
Rob Raskin

SP1984 July 1984

UNIVERSITY OF ARKANSAS

DEPARTMENT OF AGRICULTURAL ECONOMICS
AND RURAL SOCIOLOGY
222 Agriculture Building
Fayetteville, Arkansas 72701

Projected Irrigation Water Demand and Price Elasticities for the Ouachita River Basin

by

Mike Tessaro
Larry Childress
Mark Cochran
Rob Raskin

SP1984

July 1984

Projected Irrigation Water Demand and Price Elasticities
for the Ouachita River Basin*

by

Mike Tessaro**
Larry Childress
Mark Cochran
Rob Raskin

*Partial funding for this study was provided by the Corps of Engineers through contract DACW38-83-R-0031. The views expressed in the paper are those of the authors and may not reflect opinions of the Corps of Engineers.

**Tessaro and Childress are graduate assistants in the Department of Industrial Engineering; Cochran is an Assistant Professor, Department of Agri-Economics, and Raskin is a Research Associate, Department of Agri-Economics, University of Arkansas.

Projected Irrigation Water Demand and Price Elasticities for the Ouachita River Basin

In recent years, the state of Arkansas has experienced an enormous increase in its irrigated agriculture. In 1975, a state irrigation inventory indicated that there were 1,421,000 irrigated acres in the state (Shulstad, et al.). By 1980, the total irrigated acres had increased to 2,156,000 (USDA, Arkansas Statewide Study), an increase of over 50% in just five years. Three crops (rice, soybeans and cotton) account for almost the entire acreage with over 90% of the total irrigated acreage planted in rice and soybeans alone. Of these three crops, soybeans had the largest percentage increase, doubling in the five year period. Rice acreage increased 22% while irrigated cotton acreage increased approximately 50%. These increases in the use of irrigation have helped the state's farmers adapt to dynamic production conditions and to maintain the vital contribution the industry makes to the state's economy. However, in the future large increases in agricultural water demand may not be able to be met without conflicts arising from competing users.

The purpose of this study is to project the demand for agricultural water in one basin in the state and measure the likely responsiveness of the demand to changes in the costs of irrigation. The basin examined is the Ouachita River located in the south central part of the state. Projections were made for the year 1990.

The Ouachita River basin contains approximately 8,360,000 acres or roughly one quarter of the state's land. Much of the area lies in mountainous or rolling land devoted to forestry. Major land uses include forestry (81%), grassland (11%) and cropland (5%). (USDA, RIDS) Cropland is primarily concentrated on terrace soils in the four delta counties on the eastern boundary of the basin and on bottomland soils in selected valleys in other counties. The 1981 state statistics shows that there were 586,946 acres planted to rice, cotton and soybeans (The 1981 Agricultural Statistics for Arkansas). The 1980 irrigation inventory shows slightly over 50,000 irrigated acres of these crops but a discrepancy between the two years (and sources) should be pointed out. The state statistics has 115,000 acres of rice while the inventory records only 30,000 acres. A third source, the Arkansas Geological Commission estimated irrigated acreage in the basin to be about 114,000 acres in 1978 and 145,000 acres in 1980. These estimates appear to be more consistent with the state statistics (Arkansas Geological Commission).

Two recent studies have examined future agricultural water demand at a state level. Shulstad, et al., in 1978 projected the demand for 1985 and 2020 for several basins in the state. Unfortunately, they combined the Ouachita with the Tensas which lies adjacent but to the east. The latter basin has a higher proportion of cropland. In 1983, the U.S.D.A. forecasted water demand for the state for the year 2030. The forecasts for the two basins appear in Table 1.

Table 1. A Comparison of Water Demand Projections

	Shulstad, et al. 1985	Shulstad, et al. 2020	U.S.D.A. 2030
	Irrigated acres		Irrigated acres
Ouachita-Tensas	261,815	306,871	1,007,000
Ouachita	___	___	575,200

As Shumway has demonstrated, the demand for water is a derived demand based upon, ceteris paribus, the marginal value product of the water and its marginal factor cost. Comparisons of the two above studies are difficult since only single points on the demand functions are provided and no indication of the marginal factor cost of irrigation is readily available. Shumway illustrates how a derived demand for agricultural water can be estimated, displaying the responsiveness to changes in irrigations costs. In his example from California, the demand elasticities range from inelastic at low costs to very elastic at high costs. A similar procedure will be followed in this study.

Conservation practices will certainly influence the derived demand for water. Chapman argues that conservation may affect the demand curves in several different ways. Three of the common effects he discusses are: (1) a shift in demand maintaining elasticities; (2) a movement along a demand curve maintaining elasticities and not shifting the curve and; (3) a change in elasticities, maintaining the approximate position of the curve but significantly increasing the responsiveness to both high and low prices. This study will identify which of the three situations most closely approximates the derived demand in the Ouachita basin.

The Model

The procedure to identify the derived demand involves three stages: (1) the solution of a profit maximizing linear programming model; (2) some sensitivity analysis on the irrigation costs and; (3) the econometric derivation of the derived demand. Algebraically, the model can be represented as:

$$\Pi = \sum_{ijklm} [(P_i - VC_i)*Y_{ijklm} - FC_{iklm} - LC_{klm} - FIC_j - VIC_j * (W)_{ijm}]*$$

$$X_{ijklm}$$

Subject to:

$X_{ijklm} \leq acreage_{klm}$

$X_{ijlkm} \geq .64$ (1980 Census)

$X_{i3klm} \geq .04 \sum X_{ijklm}$

where Π = net revenue per acre
P = output price per unit (bushels, pounds)
X = acres
Y = expected yield per acre
VC = variable production and harvest cost per acre--excluding irrigation costs
FC = fixed production costs per acre--excluding irrigations costs
LC = land conversion costs include clearing, levelling and drainage
FIC = fixed irrigation costs per acre
VIC = variable irrigation costs per acre-inch
W = supplemental irrigation water in acre-inches
i = crops: (1) soybeans; (2) cotton; (3) rice; (4) soybean-wheat double crop
j = irrigation method: (1) dry; (2) furrow; (3) center pivot; and (4) flood
k = soil type: (1-12)
l = hydrologic region (1-9)
m = county region (1-8)

Table 2. Model Data

	Soybeans	Cotton	Rice	Wheat
Product Price	$6.59/bu	.714/lb	$4.67/bu	$3.39/bu
Dry Yield	15-29/acre	280-550/acre	----	18-35/acre
Irrigated Yield	20-35/acre	375-725/acre	85-100/acre	----
Clearing and Levelling Cost	$350/acre	$350/acre	$350/acre	$750/acre
Levelling Cost	$106/acre	$106/acre	$106/acre	$106/acre
Variable Cost	3.94/bu	.510/lb	2.65/bu	$1.809-1.836/bu
Fixed Cost	$52.35/acre	$110.55/acre	$107.08/acre	$36.32/acre

The basic data for the model appear in Table 2. These data were included in the 1980 validation runs. The product prices were derived from the five year average seasonal prices for the state cost estimates are from the Arkansas Crop Budgets produced by the Cooperative ExtensionService and the Agricultural Experiment Station. Yields were obtained from the SCS Resource Information Data System (RIDS). Yields were increased by the OBERS projections for the 1990 runs. Annual yield increases for the four crops are soybeans: 0.18 bushels; cotton: 6.67 pounds; rice: 1.32 bushels and wheat: 0.33 bushels. Costs and product prices are assumed to increase at the same rate maintaining the profit margin through time.

Water consumption and supplemental irrigation needs were calculated using the Blaney-Criddle method (SCS). Water use efficiencies by irrigation practices were increased by 10% when conservation practices were implemented. The estimates are presented in Table 3. Rainfall was determined by using levels equal to the median of county fifteen year monthly distributions.

Table 3. Water Use Efficiencies

	Without Conservation	Conservation
Furrow	.6	.7
Flood	.4	.5
Center Pivot	.8	.9

Model Validation

To validate the model, solutions for 1980 were compared with the state agricultural statistics and the water use estimates of the Arkansas Geological Commission. These comparisons appear in Tables 4 and 5.

Table 4. Validation Comparison to 1980 Census Data

	Census Acres	Model Acres	(Model/Census) X 100 %
Soybeans	331,200	264,960	80.0
Cotton	140,552	112,441	80.0
Rice	115,194	92,155	80.0
Wheat	87,908	86,314	98.2

It appears that the model is more accurate on projecting water use than on estimating the cropping pattern. Data were unavailable to validate the model for 1990. It should also be recognized that different product prices would produce different results. Future runs will test the sensitivity of results to product price changes.

Table 5. Validation Comparison to Agricultural Water Use (Arkansas Geological Commission)

	Model	A.G.C.	(Model/A.G.C.)
		(1000 acre feet)	
Rice	301.6	324.2	93.0%
Other	102.1	56.7	180.1%
Total	403.7	380.9	105.6%

Table 6. Model Results - Irrigated Acreage

Scenario	Soybeans	Cotton 100 acres	Rice
Marginal Cost of Irrigation (per acre-inch) 1) Flood = $2.51 Furrow = $1.65 Center Pivot = $4.10	269.8	88.5	73.7
2) Flood = $2.47 Furrow = $2.82 Center Pivot = $2.47	79.8	-	73.7
3) Flood = $1.49 Furrow = $1.95 Center Pivot = $2.65	266.3	88.5	90.0
4) Flood = $1.64 Furrow = $1.65 Center Pivot = $4.10	266.3	88.5	90.0
5) Flood = $1.64 Furrow = $2.82 Center Pivot = $2.47	150.0	-	73.7
6) Flood = $1.30 Furrow = $1.75 Center Pivot = $2.40	268.0	88.5	91.7
7) Flood = $4.00 Furrow = $3.10 Center Pivot = $2.70	79.8	-	73.7
8) Flood = $2.75 Furrow = $1.80 Center Pivot = $4.50	150.0	88.5	73.7
9) Flood = $3.15 Furrow = $2.50 Center Pivot = $2.25	79.8	-	73.7
10) Flood = $2.15 Furrow = $2.55 Center Pivot = $3.15	122.8	-	73.7

L.P. Model Results

For the 1990 runs, different irrigation costs were used to identify the acreage response to changes in the marginal factor cost of water. Ten different cost scenarios were considered. The irrigated acreages of the four crops associated with each scenario are exhibited in Table 6. The water use of the acreage can vary depending upon soil class, lattitude and weather pattern in each county region.

When rice goes out of solution, it is generally replaced with irrigated double crop soybeans on good croplands and with grasslands on the poorer soils. Obviously, a higher rice or cotton price should increase these acreages and lower soybean and wheat prices might result in some irrigated soybeans being forced out of solution. All rice was assumed to be grown in a one year rice and one year soybean rotation. Other rotations are used and their inclusion in the model would likely change the results.

Elasticities

The ten irrigation cost scenarios were used to estimate the derived demand for each of the crops and the total agricultural demand for the basin. Price elasticities could then be determined for each demand curve estimated. The estimated demand functions are displayed in Table 7.

Table 7. Esimated Demand Equations

Q	Intercept	Price	R^2
1990			
No Conservation			
Rice A.I.	3,758,308	-822,901 LnP (3.778)	.640
Soybean A.I.	8,062,461	-4,112,830 LnP (9.651)	.923
Total A.I.	12,463,910	-5,924,853 LnP (4.770)	.740
1990			
Conservation			
Rice A.I.	5,700,088	-2,815,810 LnP (2.800)	.417
Soybean A.I.	10,381,987	-5,311,507 LnP (7.143)	.865
Total A.I.	19,679,152	-11,025,567 LnP	.799

A.I. = acre-inches; P = irrigated cost per acre-inch. Computed T-values appear in parenthesis.

The elasticites calculated for the equations are presented in Table 8. In addition, the elasticities for the conservation scenario are included as well. The general trend uncovered by Shumway can be observed in these data--the demands are more elastic at high prices and less elastic at low prices. The curves for soybeans are more responsive than most estimated for the Western, arid regions; perhaps displaying a more competitive position for dryland agriculture in the Arkansas production environment which has more rainfall. The curves for rice were very inelastic, perhaps indicating that at the prices used, rice will dominate on those lands suitable for its production.

Table 8. Estimated Price Elasticities

Rice			Soybeans			Total		
P	Without*	With**	P	Without*	With**	P	Without*	With**
$1.75	-0.25	-0.68	$3.50	-1.41	-1.42	$2.50	-0.84	-1.15
2.75	-0.28	-0.99	4.50	-2.19	-2.22	3.50	-1.18	-1.18
3.75	-0.31	-1.42	5.50	-3.91	-4.00	4.50	-1.66	-3.56
4.50	-0.33	-1.92	6.25	-7.82	-8.19	5.00	-2.02	-5.70

*No Conservation
**Conservation

It appears with the implementation of the conservation practices, both a shift in demand and an increase in elasticities can be observed rather than a simple movement along the same demand curve. The elasticities have increased, particularly at higher prices for the conservation demands.

Once again, it should be recognized that product price changes will shift the demand curves and may alter the elasticities since cross price elasticities are ignored in the estimation of these equations.

References

1.) Arkansas Geological Commission. Use of Water in Arkansas, 1980. Water Resources Summary Number 14, Little Rock, Arkansas. 1981.

2.) Chapman, Duane. Energy Resources and Energy Corporations, Cornell University Press. 1983.

3.) Soil Conservation Service. Conservation Irrigation Guide for Mississippi. 1974.

4.) Shulstad, Robert and et al. Arkansas State Water Plan: Appendix B-Existing and Projected Water Use in Arkansas. 1978.

5.) Shumway, R. C., "Derived Demand for Irrigation Water: The California Aqueduct." Southern Journal of Agricultural Economics, 10(2), 195-700. 1973.

6.) United States Department of Agriculture. Soil Conservation Service. Arkansas Statewide Study Phase V. 1983.

7.) United States Department of Agriculture. Soil Conservation Service. Irrigation Water Requirements. Technical Release No. 21. Engineering Division. September, 1970.

8.) United States Department of Agriculture. Statistical Reporting Service. 1981 Agricultural Statistics for Arkansas. Report Series 268. August, 1982.

9.) University of Arkansas. Agricultural Experiment Station and Cooperative Extension Service. Arkansas Crop Budgets: Production Cost Estimates. Selected issues.