Programmed Effects of Surface Water Price Levels on U.S. Agricultural Water Use and Production Patterns

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The Iowa State University national interregional programming model is used to simulate increases in the price of surface water for irrigated agriculture, and to evaluate the economic impact of these increases on U.S. agricultural water use and production patterns. Four alternative price levels of surface water are analyzed with the base level being 1975 surface water prices. The model minimizes costs of endogenous agricultural production relative to projected 1985 commodity demand and resource levels. Results indicate that national surface water demand is relatively price inelastic. Surface water demand in the Great Plains is more sensitive to price increases than other regions since irrigation of the endogenous crops has less comparative advantage over dryland farming in this region than the arid West. Feed grains have the least comparative advantage in irrigation compared to soybeans and roughages. California and the Lower Colorado river basins have a comparative advantage in roughage production. As surface water prices rise, irrigated land becomes less valuable relative to dryland. Commodity shadow prices are largely unaffected by rising surface water prices mainly because irrigated agriculture contributes less than 5 percent of production of the endogenous crops in the base solution. U.S. agriculture appears able to withstand large increases in the real price of surface water without exerting much upward pressure on farm level prices of the endogenous commodities.

Agriculture in the West developed mainly with the aid of subsidized low cost water made available to farmers through public water projects. Recent developments, however, have changed the environment to one of more intense competition for available water supplies. Growth of both irrigated agriculture and the nonagriculture sector has dramatically increased water demand. Increased costs of groundwater extraction because of higher energy costs, deeper pumping depths, and depletion of nonrechargeable acquifers have raised the cost and reduced the supply of water available particularly to some segments of agriculture. In addition, Heady, et. al. and Wolman among others have shown that the value of water at the margin is considerably less in farm uses relative to nonfarm uses.

Within this new environment of increased competition, it appears, that over the future, U.S. agriculture will face reduced supplies and increased real charges for water. Thus, the need exists to identify and quantify agricultural water demand and the potential economic impacts of increased real water charges on U.S. agriculture. This paper is an attempt to partially fill that need.

The present analysis estimates an aggregate normative demand curve for surface water and explores the potential consequences of four different price levels for surface water

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Journal Paper No. J-10058 of the Iowa Agriculture and Home Economics Experiment Station, Ames, Iowa. Project No. 2104.

The authors gratefully acknowledge the helpful comments of Cameron Short, Burt English and anonymous Journal reviewers.

on agriculture through the use of a national interregional programming model. Surface water is defined in this analysis as water available to the farmer from reservoir storage or other "surface" sources such as on-farm lakes and streams, while groundwater is defined as water available to the farmer through mining or groundwater extraction.

Surface water is concentrated on for two main reasons. First groundwater price or cost is tied closely to energy prices, while surface water price is determined mainly by public institutions and reflects the cost of making water available to the farmer within a given public irrigation district. As a result, groundwater and surface water prices may diverge even in the same locality. Thus, from a farmer's viewpoint groundwater and surface water are really two different inputs in agricultural production. By parametizing surface water prices, insight can be gained into potential long run substitutibility between surface and groundwater sources. Second, surface water is concentrated on because little empirical work on agricultural surface water demand has been done. Moreover, since surface water use has never taken place in a conventional market, a statistical (positive) analysis of surface water demand is not possible. The programming model can show the potential demand for surface water, at both national and regional levels. Hence, it helps fill the quantitative knowledge gap on water demand.

Model Description

The programming model includes 105 producing areas (Figure 1) and one land class defined for irrigable and dryland farming areas. Producing areas which include irrigable land are those west of a line defined by the western boundaries of producing areas 41-47 and 39 in Figure 1. The analysis may have benefited from a multiple land class model but the increased cost, with livestock also included as endogenous activities, of solving such a model was prohibitive. Since this study is concerned with results at the national and regional level, the shortcoming of one land class is deemed not to be serious.

Both crop and livestock activities are defined by producing area. The cropping activities simulate crop rotations, chemical nitrogen and manure nitrogen supplies, and water use (on irrigated acres). The endogenous crop rotations are defined to give a range or production alternatives consistent with historical production patterns. Multiple crop activities are defined for each rotation in the irrigable producing areas to capture the nonlinear relationship between yields and water application [English and Dvoskin]

Since the present analysis is concerned with adjustments which may occur at the national level and between large regions, only crops grown nationwide are endogenous in the model. These include barley, corn, corn silage, cotton, legume hays, nonlegume hays, oats, sorghum silage, soybeans, and wheat. Important irrigated crops include pasture, orchards, vegetables, and truck cropping are left exogenous to the model. The assumption here is that these crops are high valued in irrigation and will continue to receive water over a wide range of water price increases. Livestock defined as endogenous in the model are beef cows, beef feeders, dairy, and hogs. The model selects the least cost ration, the mix of crop rotations and livestock activities within each producing area.

A competitive equilibrium is assumed in the model where all farm resources receive their market rate of return. The model minimizes production and transportation costs subject to the projected point demands of the U.S. population of 232.2 million and projected exports in 1985 [Quance, Smith, and Powell].

It might be argued that minimizing costs to satisfy projected 1985 demands may create distortions which will result in the model results not reflecting reality in the agricultural sector. However, this argument rests on the assumption that an excess demand or supply situation will persist in agriculture. Currently, no evidence exists that either of

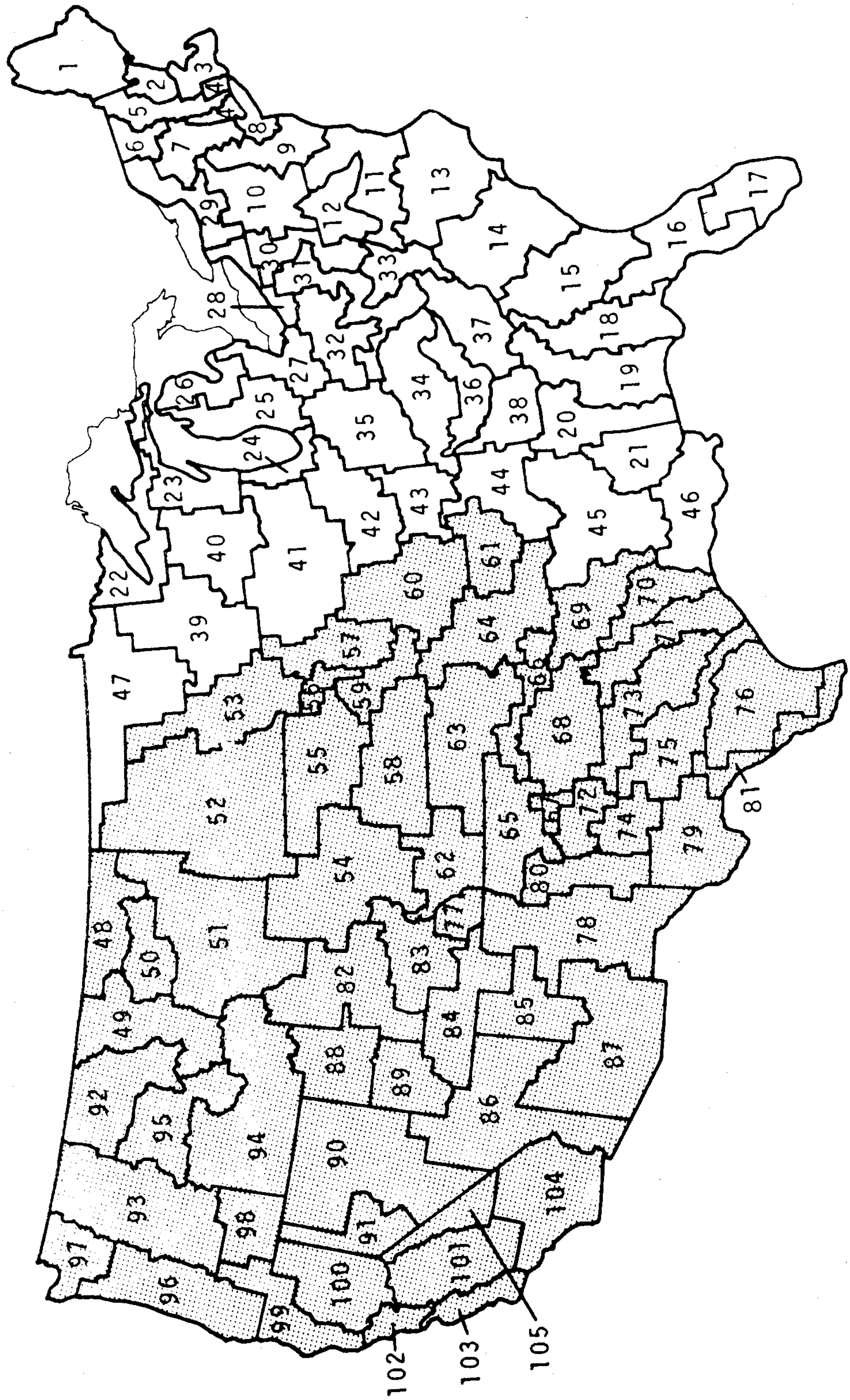

Figure 1. The 105 Producing Areas with Irrigated Lands, as Defined in the Iowa State University Interregional Programming Model.

these two alternative situations is more likely than an equilibrium situation in the long run. Since the present analysis is concerned with adjustments which may occur in response to surface water price increases in the relatively long run, the assumption of a competitive equilibrium is reasonably justified.

The transportation segment of the model is specified in per unit costs and is delineated into 28 marketing regions (Figure 2). These marketing regions are defined by trade areas around centrally located cities.

The model, upon solution, determines cropping and livestock patterns, input usage, input shadow prices and commodity shadow prices. The results are reported by river basin (Figure 3). A detailed algebraic description of the model including supplies, activities, constraints and demands is contained elsewhere [Heady, et. al.].

The conceptualization and quantification of water supplies in the model are based on work by Colette. Water supply for each irrigable producing area is divided into surface, rechargeable groundwater, and depletable groundwater. Depletable groundwater is groundwater withdrawal from aquifers in excess of the rate of recharge. Rechargeable groundwater is the amount of groundwater withdrawn from acquifers that would be replaced by natural recharge. Using the methodology developed by Collete, water supplies available to the model are adjusted for projected 1985 water consumption by exogenous crops, livestock, and for the nonfarm sector.

The model allows surface water to be transferred between producing areas within a river basin by natural flows and by man-made transfer facilities. Surface water transfer is conditional with respect to various treaties and water compacts. Transfers between producing areas in different river basins are allowed where man-made diversion facilities now exist or are under construction. Base surface water price within each irrigable producing area is a weighted average of the price of an acre foot of water delivered to farmers by Bureau of Reclamation projects within the area [Collete]. Prices of both depletable and rechargeable groundwater were developed from survey data and represent the average cost to the farmer of pumping and applying groundwater in each producing area. Depletable and rechargeable groundwater are priced the same within any given producing area. Actually, depletable and rechargeable groundwater supplies should not be priced the same since mining depletable groundwater increases the future retrieval cost of groundwater. However, lack of data forces this simplifying assumption. Institutional constraints on groundwater usage are left out of the model to determine what the substitutability between surface water and groundwater would be in the absence of institutional constraints on water use.

Surface Water Pricing Alternatives

Four surface water price levels are used to simulate surface water prices. These price levels are as follows: (a) The base surface water price level (GW1SW1), generally the 1975 level of water prices, (b) double the base surface water price level (GW1SW2), (c) triple the base surface water price level (GW1SW3), and (d) quadruple the base surface water price level (GW1SW4). Prices of both rechargeable and depletable groundwater are held constant at their 1975 level. Of course, these water price alternatives may not correspond to the actual situation in 1985. However, these price alternatives are necessary to yield an aggregate demand curve for surface water such that the price of all other inputs including groundwater remain constant. Also of primary interest are the amount of water use and its relative responsiveness which might prevail if alternative levels of surface water prices are possible. For the purposes of this normative analysis and to understand better what water demand and allocation in agriculture could be if surface water prices were at different levels and water were able to move to its use of greatest marginal value productivity, parametric price programming is used to evaluate these alternatives. The wide range

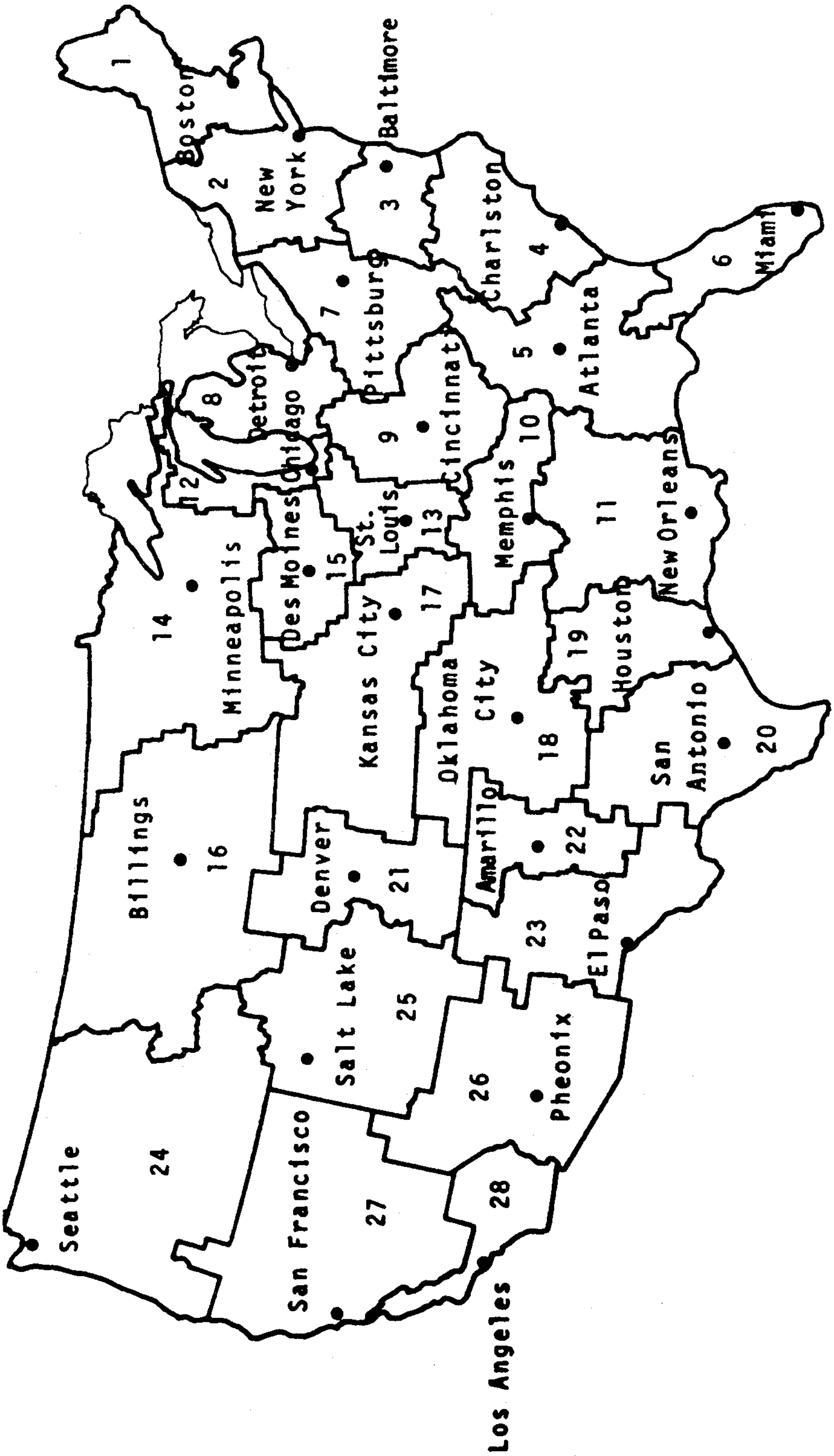

Figure 2. The 28 Market Regions with Central Cities, as Defined in the Iowa State University Interregional Programming Model.

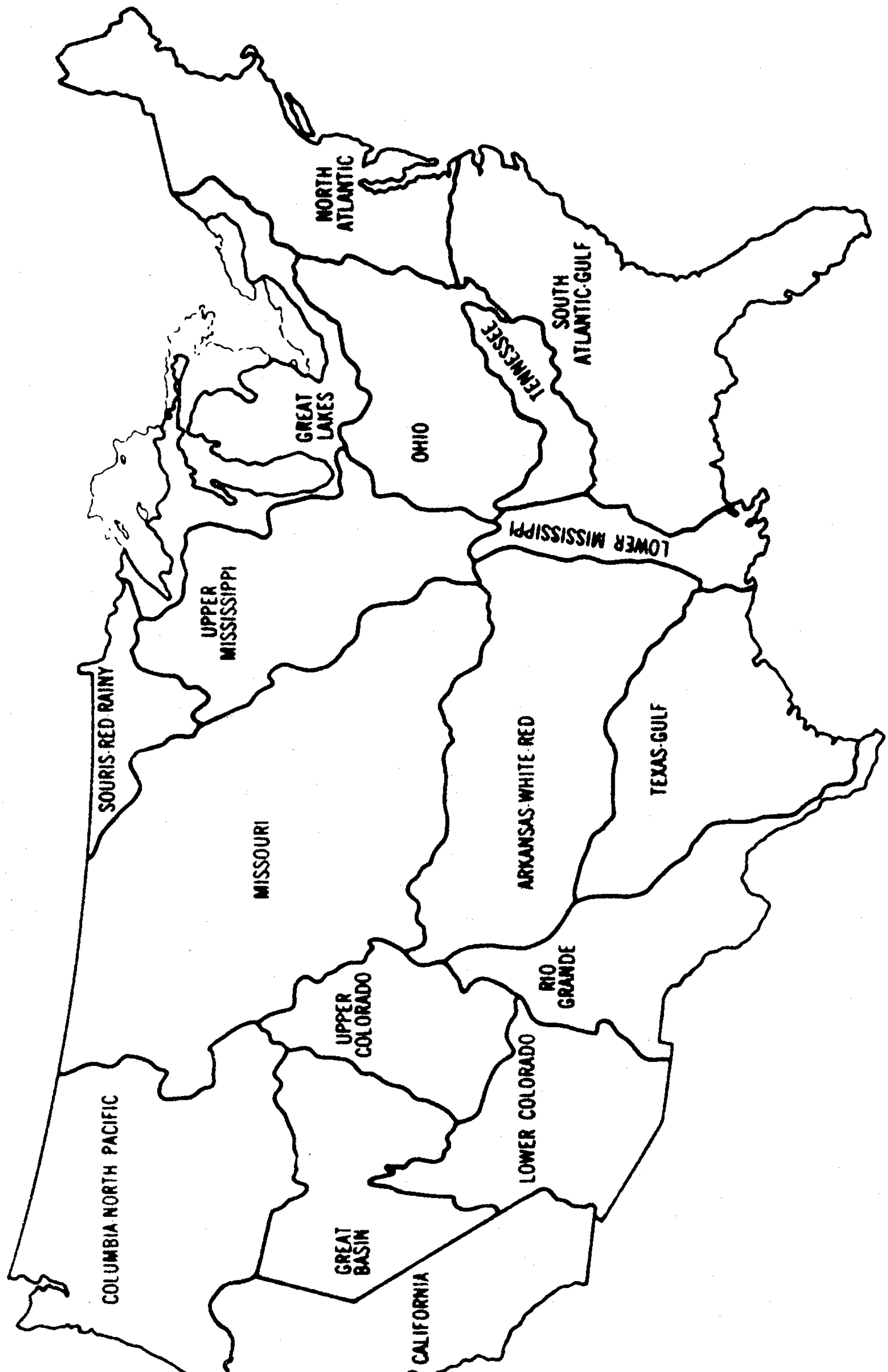

Figure 3. River Basins as Defined by the Water Resources Council.

of surface water price alternatives considered allow generation of a large amount of information relative to solution costs.

Empirical Results

Water Use

U.S. water use for both exogenous and endogenous crops and livestock is reported by major river basins for the four price levels in Table 1. The base solution shows the mix of surface and groundwater use in each river basin under the initial assumptions of the model. Surface water accounts for 69 percent of total agricultural water use in the base solution. At each level of surface water prices, total surface water use falls as groundwater substitution for surface water occurs but is not complete. Total water use falls at each price level. Between the lowest and highest levels, total water use falls 19 percent from 50.46 to 40.98 million acre feet. This result in general suggests that total water use is not particularly sensitive to large increases in the real price of surface water because of extensive groundwater substitution. Groundwater use rises 82 percent from 15.49 to 28.32 million acre feet between the lowest and highest price levels. It may be argued that the model overstates the substitutability between ground and surface water since pumping costs should actually increase with groundwater use. However, since groundwater prices vary widely between producing areas (ranging from \$2.77 to 26.41 per acre foot), as groundwater substitution takes place in the model, more expensive groundwater is utilized resulting in increased average price of utilized groundwater for each higher level of surface water prices.

On a regional level, only the Arkansas-White-Red and the Texas-Gulf basins utilize more groundwater than surface water in the base solution. When surface water prices are doubled, all river basins experience a decrease in surface water use with the exception of Lower Colorado which slightly increases surface water use.

The majority of surface water used in the Lower Colorado is transferred from the Upper Colorado and adjusted for conveyance losses. The relatively low price of surface water in the Upper Colorado is a major reason for inelastic surface water demand in the Lower Colorado at any of the price alternatives. Surface water bought and utilized within the Upper Colorado is also quite insensitive to price increases for the same reason. The remaining basins all experience decreases in surface water use ranging from about 10 percent in Great Basin and Columbia-North Pacific to 74 and 69 percent in Arkansas-White-Red and Rio Grande, respectively, when prices are doubled.

When surface water prices are tripled, decreases in surface water use, with respect to base solution levels, range from 88 percent in Rio Grande to 6 and -17 in Upper Colorado and Lower Colorado, respectively. At this price level, the remaining basins have reduced surface water use on the order of 50 to 70 percent from their original levels. When prices are quadrupled, decreases in surface use are greatest in the Missouri and Rio Grande basins at 97 and 96 percent, respectively. The Colorado basins remain the most price insensitive at this level. California reduces surface water use 66 percent, the least among the remaining basins, from the base level.

In general, increases in groundwater use mirror decreases in surface water use at any price alternative. These water use figures can best be interpreted by examining the arc elasticities of demand and at both the national and river basin levels shown in Table 2.

Price Elasticities

Arc elasticities of demand are calculated for each price interval by dividing the percentage change in surface water use by the percentage change in surface water price. On a national level, the demand for surface water appears to be relatively inelastic. The arc elasticities range between $-.25$ at the lowest price interval and $-.83$ at the highest price interval.

TABLE 1. U.S. Water Use (000 Acre-Feet) for Irrigation of All Crops and Livestock by Major River Basins for Four Price Levels in the Year 1985

	Price Levels							
	(Base) GW1SW1		GW1SW2		GW1SW3		GW1SW4	
River Basin	Ground	Surface	Ground	Surface	Ground	Surface	Ground	Surface
Missouri	2,223.3	5,142.0	4,416.8	2,014.9	4,485.1	1,046.6	4,604.2	132.7
Arkansas-White-Red	2,935.5	1,757.6	3,979.0	462.4	4,011.1	463.0	4,096.1	462.9
Texas-Gulf	4,017.5	2,701.0	4,347.6	1,481.0	4,357.1	1,072.3	4,361.5	1,009.2
Rio Grande	840.4	1,069.8	1,527.8	327.8	1,614.3	130.8	1,614.3	42.4
Upper Colorado	0	3,683.7	0	3,495.74	0	3,460.7	0	3,229.4
Lower Colorado	810.8	952.2	803.8	1,110.6	806.0	1,117.8	802.7	1,117.82
Great Basin	0	1,220.5	0	1,114.0	0	1,052.7	334.6	278.8
Columbia-North Pacific	473.2	6,031.0	1,017.0	5,434.7	1,073.8	2,717.0	2,947.8	778.4
California	4,187.9	12,673.4	4,576.0	10,898.3	9,082.1	6,393.2	9,549.6	5,607.4
U.S.	15,488.9	34,976.3	20,668.0	26,339.4	25,429.5	17,454.4	28,320.8	12,659.0
U.S. Total Water Use	50,464.9		47,007.4		42,883.9		40,979.8	

TABLE 2. Arc Elasticities of Demand for Surface Water and Percentage Changes in Arc Elasticities Under Four Surface Water Price Alternatives in the Year 1985

River Basin	Price Intervals				
	GW1SW1/GW1SW2[a]	GW1SW2/GW1SW3[b]		GW1SW3/GW1SW4[c]	
Missouri	−.61	−.96	(−57)[e]	−2.62	(−173)[f]
Arkansas-White-Red	−.74	0	(100)	0	(d)
Texas-Gulf	−.45	−.56	(−24)	−.18	(68)
Rio Grande	−.69	−1.20	(−74)	−2.04	(−70)
Upper Colorado	−.05	−.02	(60)	−.20	(−900)
Lower Colorado	.17	.02	(−88)	0	(−100)
Great Basin	−.08	−.12	(−50)	−2.21	(−1742)
Columbia-North Pacific	−.10	−1.0	(−900)	−2.13	(−113)
California	−.14	−.82	(−486)	−.37	(55)
U.S.	−.25	−.67	(−168)	−.83	(−24)

[a]Arc elasticities are figured from GW1SW1 price and quantity to GW1SW2 price and quantity.
[b]Arc elasticities are figured from GW1SW2 price and quantity to GW1SW3 price and quantity.
[c]Arc elasticities are figured from GW1SW3 price and quantity to GW1SW4 price and quantity.
[d]Not calculated because of division by zero.
[e]Percentage change in arc elasticities between the first and second price intervals.
[f]Percentage change in arc elasticities between the second and third price intervals.

When comparing surface water demand between basins or comparing demand in a basin with national demand it is not helpful to compare arc elasticities directly since the arc elasticities for any price interval represent different points on each basin's demand curve. Thus, percentage changes in arc elasticities are calculated as a means to show the relative sensitivity of surface water demand. The figures in parentheses in column two of Table 2 are percentage changes in arc elasticities between the first and second price intervals while the corresponding figures in column three are percentage changes in arc elasticities between the second and the third price intervals. Negative values suggest that the demand curve is growing more elastic and vice-versa. Between the first and second price intervals only Arkansas-White-Red and Lower Colorado, have nonnegative values which suggests that these basins have less elastic demand for surface water than the remaining basins. Interestingly, only California and Columbia N. Pacific have more elastic surface water demand that the nation as a whole between these price intervals. Between the second and third price intervals, Texas-Gulf and California have the most price inelastic demand (the only positive values in this column). The remaining basins with the exception of Arkansas-White-Red (not calculated) are more elastic than the nation as a whole. In Table 3 river basins and the U.S. as a whole are ranked by surface water demand sensitivity for both price situations.

Irrigated Acreage and Cropping Patterns

Total irrigated acreage of endogenous crops decreases at each higher surface water price level (Table 4). The programmed base solution indicates 19.5 million acres of endogenous irrigated crops in 1985 compared to 16.0 million acres when surface water prices are quadrupled. In other words, total irrigated acreage falls to 82 percent of its base level when surface water prices are quadrupled. Total dryland acreage increases by approximately the same amount as total irrigated acreage decreases when surface water prices are quadrupled. The Missouri basin accounts for 75 percent of the decrease in

TABLE 3. River Basins and U.S. Ranked by Sensitivity of Surface Water Demand for the First to Second and Second to Third Price Intervals

	First/Second	Second/Third
↑	Columbia-North Pacific	Great Basin
	California	Upper Colorado
	United States	Missouri
	Lower Colorado	Columbia-North Pacific
elastic	Rio Grande	Lower Colorado
	Missouri	Rio Grande
	Great Basin	United States
	Texas-Gulf	California
	Upper Colorado	Texas-Gulf
	Arkansas-White-Red	

total irrigated acreage when surface water prices are doubled. Irrigated acreage in the remaining basins remain virtually unchanged when prices are doubled as groundwater is substituted for surface water in these basins. When prices are tripled and quadrupled the Missouri basin is again the only basin which experiences a significant decrease in irrigated acreage. The evidence suggests that the Missouri basin has less advantage in irrigation of the endogenous crops compared to the other irrigable basins.

Crops in order of total irrigated acreage in the base solution are roughages, corn, wheat, sorghum, barley, cotton, and soybeans. Over the range of surface water price levels, irrigated acreage of corn, cotton, and roughages tecrease the most in absolute terms by 1.4, .8, and .8 million acres, respectively.

Regional changes in irrigated feed grains, soybeans, and roughages are shown in Table 5. In percentage terms, feed grains fall out of irrigation faster than soybeans or roughages. When surface water prices are doubled, irrigated feed grain acreage declines are 31 and 75 percent in the Missouri and Lower Colorado basins, respectively, while irrigated acreage of roughages falls less than 10 percent in any irrigable basin. Irrigated soybean acreage falls 26 percent in the Missouri basin and to zero in the Arkansas-White-Red basin. However, Arkansas-White-Red has very little irrigated soybean acreage even in the base solution.

When surface water prices are doubled, Rio Grande, Upper Colorado, Columbia North Pacific, and California basins experience little or no change in irrigated acreage of feed grains, roughages, and soybeans. Texas-Gulf actually experiences an increase in irrigated feed grains, however this is coupled with a large fall in irrigated cotton not shown in the table. When surface water prices are tripled and quadrulpled all but the Arkansas-White-Red and California basins experience decreases in irrigated acreage of the three crop categories.

Results suggest that of these categories of irrigated crops, acreage of feed grains fall faster in response to increased water price particularly in the Great Plains. On the other hand, irrigated acreage of roughages are affected the least. Lower Colorado and California appear to have a comparative advantage in roughage production. Irrigated feed grain acreage is insensitive to water price increases in the California basin. This apparently is caused by the low base price of surface water and the large amount of groundwater available as a substitute (relative to other irrigable basins).

Land and Commodity Shadow Prices

Land shadow prices in this linear programming model can be used to represent rental values per acre of agricultural land for 1985. In a competitive market, the present value of a stream of annual rental payments for a particular type of agricultural land represents the approximate value of that type of

TABLE 4. Irrigated and Dryland Acres Harvested by River Basin, and Irrigated Acreage by Corn for Four Price Levels in the Year 1985

River Basin	Price Levels								
	Base (GW1SW1)		GW1SW2		GW1SW3		GW1SW4		Total Available Cropland
	Dry	Irrigated	Dry	Irrigated	Dry	Irrigated	Dry	Irrigated	
	Million Acres								
New England	1.2	-	1.1	-	1.2	-	1.2	-	1.4
Mid Atlantic	9.1	-	9.1	-	9.1	-	9.1	-	9.7
South Atlantic-Gulf	21.4	-	21.0	-	21.6	-	21.7	-	25.0
Great Lakes	22.3	-	22.3	-	22.3	-	22.3	-	24.0
Ohio	29.9	-	29.9	-	29.9	-	29.9	-	30.3
Tennessee	3.7	-	3.7	-	3.7	-	3.7	-	3.8
Upper Mississippi	61.2	-	61.2	-	61.3	-	61.3	-	62.2
Lower Mississippi	19.6	-	19.6	-	19.6	-	19.6	-	21.3
Souris-Red-Rainy	18.7	-	18.7	-	18.7	-	18.7	-	20.1
Missouri	89.0	4.8	89.8	3.9	90.3	3.4	90.1	3.1	96.0
Arkansas-White-Red	40.8	2.5	40.8	2.5	40.8	2.5	40.7	2.5	43.6
Texas-Gulf	20.5	2.8	20.8	2.5	21.0	2.3	21.0	2.3	24.4
Rio Grande	.5	1.2	.6	1.1	.6	1.0	.7	1.0	2.5
Upper Colorado	.3	.9	.3	.9	.3	.9	.4	.8	1.2
Lower Colorado	.8	.5	.8	.5	.8	.5	.8	.5	1.5
Great Basin	1.0	.6	1.0	.5	1.0	.5	1.0	.5	2.2
Columbia-North Pacific	13.9	1.7	13.9	1.7	14.9	.7	14.9	.7	17.3
California	2.5	4.6	2.4	4.6	2.4	4.6	2.4	4.6	10.0
U.S. Total	356.3	19.5	357.6	18.3	359.4	16.5	359.9	16.0	396.8
<u>Crop</u>									
Barley		1.3		1.2		1.1		1.0	
Corn		4.1		4.1		3.1		2.7	
Cotton		1.3		.6		.5		.5	
Oats		.35		.35		.35		.35	
Sorghum		2.35		2.1		2.1		2.1	
Roughages[a]		6.2		6.0		5.4		5.4	
Soybeans		1.0		1.1		1.1		1.1	
Wheat		3.0		2.9		2.8		2.75	
U.S. Crop Total[b]		19.5		18.35		16.45		16.0	

[a]Includes corn silage, sorghum silage, legume hay and nonlegume hay.
[b]May not add because of rounding.

TABLE 5. Cropping Patterns on Irrigated Land by River Basin for Four Price Levels in Year 1985

	Price Levels											
	BASE[a]/GW1SW1 (000 acres)			GW1SW2 (% of base)[d]			GW1SW3 (% of base)[d]			GW1SW4 (% of base)[d]		
River Basin	Feed Grains[b]	Soybeans	Roughages[c]	Feed[b] Grains	Soybeans	Roughages[c]	Feed Grains[b]	Soybeans	Roughages	Feed Grains[b]	Soybeans	Roughages
Missouri	1848	772	2141	69	74	95	40	74	99	21	74	100
Arkansas-White-Red	1501	62	908	96	0	100	100	100	101	102	100	104
Texas-Gulf	1094	139	294	126	100	100	126	100	26	127	100	26
Rio Grande	682	0	482	100	—	95	91	—	87	78	—	87
Upper Colorado	754	0	188	100	—	100	99	—	95	96	—	66
Lower Colorado	124	0	373	25	—	99	22	—	99	22	—	99
Great Basin	186	0	368	91	—	92	90	—	91	88	—	91
Columbia-N. Pacific	1129	0	615	100	—	100	43	—	31	43	—	31
California	3754	0	796	99	—	100	100	—	101	100	—	102

[a]Absolute figures in 000 acres for the base solution.
[b]Includes barley, corn, oats, and sorghum.
[c]Includes legume hay, nonlegume hay, corn silage and sorghum silage.
[d]Base equals 100%. Refer to BASE for absolute figures of the base solution.

land at the margin. Market values of land may be higher than rental evaluations because of speculation about future land use or changes in the agricultural setting [Greenbalgh and Stewart]. Land as a productive resource is not a homogenous input. However, for the present analysis a one land class model was used for reasons mentioned earlier.

Table 6 list land shadow prices for the four surface water price alternatives. It should be remembered that the land shadow prices, particularly in the Western basins, will be significantly lower than actual rental values in these basins since shadow prices are determined by the marginal or lowest valued grown in the region. The land shadow prices do represent the value of an additional acre of endogenous crop production to the model as a whole. Rising surface water price has an upward impact on dryland shadow prices in both irrigable and nonirrigable river basins. Dryland shadow prices in nonirrigable basins increase through all four price levels since land becomes relatively more scarce as less water is used in production. Most of the increase in dryland basins shadow prices occurs during the initial doubling of surface water prices. Land shadow prices in dryland basins rise an average of 3.6 percent with the Great Lakes basin at the low end of the range at 2.6 percent and the New England basin at the high end with 5.6 percent when surface water prices are doubled. In the irrigable basins, dryland shadow prices increase an average of 4.9 percent.

Irrigated land shadow prices tend to fall at each higher price level. However, there are several exceptions in which the value of irrigated land rises as water prices rise. When water prices are raised, some irrigated land rents can be expected to rise since the remaining irrigated acres are relatively more valuable. Also irrigated land rents may rise in some basins as marginal irrigable land falls out of irrigation. It is not only important whether or not irrigated land rents rise or not, but also whether irrigated land becomes more or less valuable relative to dryland in

TABLE 6. Land Shadow Prices by River Basin for Four Price Levels in the Year 1985

River Basin	(GW1SW1) Base		GW1SW2		GW1SW3		GW1SW4	
	dry	irrigated	dry	irrigated	dry	irrigated	dry	irrigated
	(dollars per acre)							
New England	45.57	-	48.13	-	48.19	-	48.46	-
Mid Atlantic	46.31	-	47.75	-	47.77	-	48.30	-
South Atlantic-Gulf	27.52	-	28.61	-	28.57	-	29.07	-
Great Lakes	46.38	-	47.64	-	47.75	-	48.42	-
Ohio	50.06	-	51.37	-	51.50	-	52.24	-
Tennessee	25.00	-	26.05	-	26.17	-	26.97	-
Upper Mississippi	42.18	-	43.37	-	43.49	-	44.12	
Lower Mississippi	29.39	-	30.68	-	30.58	-	30.96	-
Souris-Red-Rainy	18.48	-	19.05	-	19.19	-	19.30	-
Missouri	27.17	39.53	27.97	38.08	28.13	37.66	28.46	37.89
Arkansas-White-Red	35.09	35.75	36.03	36.03	34.63	34.63	33.80	33.80
Texas-Gulf	18.87	18.87	19.48	19.48	17.26	17.26	17.50	17.50
Rio Grande	12.78	33.04	13.21	31.40	13.42	24.62	13.40	23.77
Upper Colorado	4.37	39.77	4.85	39.43	4.96	39.40	5.10	39.19
Lower Colorado	10.04	13.77	10.94	14.69	11.10	14.83	11.32	15.12
Great Basin	17.05	17.34	18.23	18.50	17.94	19.73	17.66	17.66
Columbia-N. Pacific	29.41	43.80	30.62	42.25	27.76	38.68	27.97	38.92
California	5.13	21.38	5.23	16.89	5.45	16.56	5.70	16.37

the same basin. Increased water prices can be expected to reduce the value of irrigated land relative to dryland because the yield advantage of irrigated land is offset by higher costs of production. This can be examined by calculating the percentage change in absolute deviation between dry and irrigated land as water price rises. Shadow prices of dry and irrigated land tend to converge in all irrigable basins except Lower Colorado between the lowest and highest surface water price alternative. Moreover, the convergence between dry and irrigated land values is rather substantial ranging from 3.7 percent in Upper Colorado to 48.8 percent in Rio Grande.

Land shadow prices generated by the model are useful in gaining an insight on the income redistribution effects within agriculture which might result if these water price alternatives were realized. The capitalized difference between irrigated and dry land shadow prices represent a rough measure of gain or loss at each level of higher water prices relative to the base water price.

National commodity shadow prices for the major endogenous commodities are shown in Table 7 for the four price alternatives. Between the base and highest surface water price alternative, none of the major commodities experiences more than a 2 percent rise in its shadow price. This result suggest that U.S. agriculture could withstand a large increase in the real cost of surface water for irrigation without great upward impact on commodity prices.

TABLE 7. Major Commodity Shadow Prices for the U.S. Under Four Price Levels in the Year 1985

Commodity	Units	Price Levels (Base) GW1SW1	GW1SW2	GW2SW2	GW1SW4
Corn	bushels	1.66	1.66	1.65	1.66
Wheat	bushels	2.65	2.67	2.66	2.67
Oil Meals	CWT	8.86	8.94	8.96	9.02
Legume Hay	tons	41.73	42.08	42.25	42.45
Cotton	bales	151.65	152.57	152.43	152.52
Pork	CWT	42.18	42.41	42.36	42.45
Milk	CWT	5.69	5.72	5.72	5.73
Fed Beef	CWT	77.60	78.13	78.31	78.49

Conclusions

The results of the analysis suggest that national agricultural demand for surface water is relatively inelastic with respect to own price changes. Surface water demand in the great Plains is more sensitive to own price increases than other irrigable areas, mainly because irrigation of the endogenous crops has less comparative advantage over dryland farming in this area than the arid West.

Without institutional constraints on groundwater usage, rising surface water prices cause groundwater to be used at a much faster rate than would otherwise be the case particularly in the Missouri, Arkansas-White-Red, Texas-Gulf, and Rio Grande basins.

Feed grains have the least comparative advantage in irrigation compared to soybeans and roughages. They fall out of irrigation most quickly when surface water prices increase. On the other hand, irrigated acreage of roughages are quite insensitive to water price increases in the Lower Colorado and California basins suggesting that these areas have a comparative advantage in roughage production.

As surface water prices rise, irrigated land becomes less valuable relative to dryland. Dryland values rise more in river basins where irrigation exists than in basins where only dryland farming is practiced. In general, as surface water prices rise irrigated and dryland values within a given basin tend to converge. This convergence occurs to the greatest extent in Rio Grande and least in the Lower Colorado basin. Since irrigated agriculture contributes less than 5 percent of production of the endogenous crops in the base solution, commodity shadow prices are largely unaffected by rising surface water prices. Thus, U.S. agriculture can, apparently, withstand large increases in the real price of surface water used for irrigation without exerting much upward pressure on farm level prices of the endogenous commodities.

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