A METHOD FOR ESTIMATING THE VALUE OF WATER AMONG SECTORS OF A REGIONAL ECONOMY

Mark S. Henry and Ernie Bowen

Recent trends in the southeastern states toward increased use of irrigation in agriculture may be attributed to risk aversion management by farmers in response to recent drought periods. Despite ample annual average rainfall in the Southeast during the growing season, the vicissitudes of rainfall patterns provide sufficient reason to consider irrigation for field crops as well as for vegetables and fruit (Ganguly). Increased use of irrigation additionally results in new demands for water in rural areas.

It is also well documented that nonmetropolitan areas are experiencing substantial rates of positive net immigration (Wardell and Gilchrist). In the Southeast, there is a trend for new manufacturing plants to locate in rural areas where wages, taxes, and union activity are at low levels. As growth occurs in these nonmetropolitan regions, industrial, residential, and commercial activities require additional supplies of water.

Although water supplies are adequate or abundant on the average in the Southeast, there are areas where serious supply problems exist relative to short-term variance, as argued by Ganguly, or to long-term average availability. For example, in South Carolina there is considerable concern that salt-water intrusion into fresh-water aquifers along the coast will seriously affect the capacity of these rapidly growing regions of the state to sustain current growth rates. Many areas that have already experienced significant growth are rapidly becoming aware of the constraint to growth of an inadequate water supply. This constraint is that much more binding and complex because of the unique nature of property rights governing water use. The lack of a functioning market mechanism for water can and does result in gross inefficiency.[1]

Under these conditions, a planning agency concerned with the dual goals of economic development and control of the quality of water resources needs a method by which it can evaluate the impact of growth (actual or desired) on regional water resources. In extreme cases where planning goes beyond encouraging the appropriate kind of economic development to actually devising a pricing mechanism for the allocation of scarce water resources, a method for estimating the marginal value of water to alternative users is needed.[2]

The main objective of the pricing mechanism is to ensure the transfer of resources from lower value of marginal product uses to higher value of marginal product uses. This transfer will continue until the value of marginal product of the resource in any one of its uses is the same as its value of marginal product in all of its other uses. Once this condition is met, welfare is maximized in the resource market. In a competitive market system, prices are the vehicle by which the transfers occur.

While the pricing mechanism is an effective, efficient allocator of resources under competitive market conditions, it ceases to function efficiently when noncompetitive conditions prevail, and where property rights to the resource inhibit free mobility of the resource. If the price of the resource does not reflect the value of the marginal product, the allocation mechanism can no longer function in an efficient manner. These limitations come into play in the case of water resources.

This article develops a method for evaluating alternative industry groups in an economic growth/water-use tradeoff framework and presents a method for estimating water's marginal value to alternative users; the framework employs input-output and linear programming methods.

Related Literature

A comprehensive analysis of the demand for and value of water resources necessitates a broad view of the economic structure of the region in question. This viewpoint was embraced by the United Nations Department of Social and Economic Affairs some 25 years ago, and by such eminent economists as Howe and Fox. In es-

[1] Kiker and Lynn provide an excellent review and analysis of some nonmarket mechanisms currently in use to allocate water supplies. In addition, they discuss Eastern U.S. groundwater law as it evolved from common law doctrines.

[2] Kiker (p. 30) in discussing his limited economic information (LEI) approach to water resource allocation concluded that "to apply the approach (LEI), the water authority must estimate economic values for various water uses. Water is allocated to the various water uses so that the economic value of the last unit of water used in an activity is equal to that used in every other activity."

sence, policy formulation with respect to water development, allocation, and use may be fundamentally incorrect if based upon an incomplete view of the regional economic structure.

Each sector's water demands must be viewed in relation to total available supplies. Sectors compete for existing supplies, but each sector's continued existence is partially dependent upon availability of water to competitors. A particular sector requires water, as well as the output of other sectors, as input into its productive facilities. Sectors are economically interdependent, and each is dependent upon water availability. A shortage of water in a particular sector may thus indirectly restrict delivery to final demand by several sectors.

The applications of the general equilibrium methods of input-output and linear programming to water resources planning are of relatively recent origin. Nevertheless, their fundamental role in water resources planning and development is quite well established. Stoevener and Castle have offered possibly the most severe criticism of such methods, yet were unable to refute their potential propriety.

Other research has exhibited the joint use of input-output and linear programming techniques. The framework is quite useful for economists in determining efficient allocation of scarce resources among competing users, according to prescribed social objectives and within the technological structure of the economy. The work of Lofting and McGauhey (1963, 1968); Tijoriwala et al.; and Kelso et al. is representative of such endeavors. Several theoretical and applied input-output linear programming models are provided by Richardson.

By itself, input-output allows one to estimate the change in regional output and value added from a given change in final demand for the goods and services produced in a region. While some sectors of the regional economy produce mainly for final demand (e.g., exports of soybeans), other sectors produce goods for local consumption, and as inputs to other sectors within the region. The strength of input-output is the empirical recognition of these interindustry linkages for each of the sectors of the economy. In essence, the problem in input-output analysis is to find the levels of output required from each sector to support the final demand for the region's goods and services, given a known process for producing each activity. As such, IO can be used to find the total output and resources required to support final demand delivery.

On the other hand, linear programming (LP) searches for the optimum set of activities in an economy consistent with the objective function, e.g., to maximize gross regional product. In so doing, LP allocates activity between sectors to achieve the objective, while meeting the constraints to production in each sector. By varying

these constraints—for example, water available to the region—the value of additional resources to the region may be evaluated.

By obtaining the technical coefficients matrix A from the input-output model of the regional economy, the regional interindustry structure is estimated. Each column in the A matrix represents the fixed coefficients production function for that sector. Moreover, the basic IO balance equations require that total gross output less intermediate use be greater than or equal to final demand deliveries. By viewing these IO balance equations as constraints to sectoral output levels, the structure of the regional economy can be linked to the general LP format.

With a combined IOLP format, interindustry requirements and primary resource (labor and water in our case) requirements are explicit in the model structure. We still solve for the level of sectoral output; but now we are required to achieve a distribution of sectoral output levels that will maximize gross regional product subject to structural constraints (the A matrix), final demand delivery constraints (to reflect the region's external trade pattern), and primary resource constraints of labor and water. Manipulation of the IOLP model allows estimation of the value of water to alternative sectors of the regional economy, given these constraints and the objective of maximizing gross regional product.

Model Structure

The model employed in this study consists of a nonsurvey regional input-output model (64 sectors) and a linear programming framework (IOLP) that may be written as:

Maximize the objective function

(1) $Z = CX$

subject to

(2) $\hat{Y} \geq (I - A) X \geq Y$

(3) $\sum_{i=1}^{n} w_i X_i \leq W_0$

(4) $\sum_{i=1}^{n} l_i X_i \leq L_0$

where

i (or j) = number of the sector
n = number of sectors
Z = gross regional product
C = value added coefficients vector (dimension 1 × n)
X = gross output vector (dimension n × 1)

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$(I - A)$ = I is the identity matrix; A is the technical coefficient matrix

Y = final demand vector (dimension n × 1), current level

$\hat{Y}$ = final demand vector (dimension n × 1), projected level

w_i = sectoral water intake per dollar of gross output

W_o = total water availability

l_i = sectoral labor requirements per dollar of gross output

L_o = total labor availability

The IOLP framework may be used to solve for the optimal allocation of activity between alternative sectors of the regional economy in several different ways. First, by specifying the Y sector and W_o and L_o constraints to be equal to 1980 levels, a base level of activity (X) is established. By next allowing the L_o constraint to increase, the desired level of new activity may be estimated for each sector in order to maximize gross regional product (GRP).

Second, the marginal value of additional water supplies to the region can be assessed by varying the W_o parameter and solving for the shadow price of water. Third, the relative average value of water to the GRP across sectors may be estimated using the IO model as follows:

(5) $\quad Z = s\,[W(I-A)^{-1}]$

(6) $\quad r_i = \dfrac{q_i}{z_i}\ i=1 \ldots, 64$

W = diagonal matrix with w_i along the principal diagonal, 64 × 64

s = unit column summation vector, 1 × 64

Z = vector showing direct, indirect and induced water used per dollar delivery to final demand by each sector, 1 × 64, $z_i = z_1 \ldots z_{64}$

q_i = household row entry of the $(I-A)^{-1}$ matrix which yields direct, indirect and induced income per dollar delivery to final demand by sector, 1 × 64

r = vector showing the change in total income to change in total water-use ratio for each of the 64 sectors for a dollar delivery to final demand, 1 × 64

Finally, the relative *marginal* value of allocating water to alternative sectors may be estimated by comparing the optimal output levels of each of the 64 sectors of the model under different levels of W_o.

A Case Study of Central South Carolina

A multicounty region in central South Carolina was the study area. The IO model was constructed using the 1972 United States model up-

dated to 1980 prices and modified by the simple location quotient approach (see Mulkey-Hite for a complete description of the nonsurvey technique used). Regional sectoral exports were estimated as the residual between in-region requirements and total output by sector. The IO model is closed with respect to households and government. Accordingly, the export vector is used as the estimated Y vector in the IOLP model. The w_i coefficients were obtained from a survey of all manufacturing firms in the region (South Carolina Department of Labor), published data on agricultural output (South Carolina Crop and Livestock Reporting Service), a survey of South Carolina farm irrigation practices (Clemson University, Department of Agricultural Engineering), and from United States Geological Survey data for most other sectors. W_o and L_o were obtained from the South Carolina Water Resources Commission and the Employment Security Commission, respectively.

The Value of Water in Alternative Uses

The results of the IOLP analysis are given in Tables 1, 2, and 3. Table 1 displays the shadow price of water at various levels of availability (W_o).

Water becomes a constraint to GRP growth at about the 45,000-acre-foot-level of water availability. The marginal value of an acre-foot of water to GRP is constant over a long range (17,200 acre-feet to 46,000 acre-feet). If water availability falls below the 17,200 level, the shadow price increases significantly. The current surface water capacity (systems in place) is about 30 percent above the level where water becomes an effective constraint. Thus, for this aggregate region, on average, water availability is not currently a serious problem.

To evaluate the relative value of water in alter-

TABLE 1. Shadow Price of Water at Alternative Supply Levels, Low Agricultural Water Demand

Water Supply (acre-feet)	Shadow Price (dollars)	Range of Shadow Price (dollars)	Optimal Gross Regional Product (millions dollar)
68,000	0	45148+	1,184
45,168	0	45148+	1,184
44,148	681	17,250-45,148	1,184
17,200	7,934	17,111-17,250	1,165
17,105	14,717	17,100-17,111	1,164
17,000	15,138	16,923-17,100	1,163
16,800	27,799	16,513-16,923	1,152
16,510	29,493	16,508-16,513	1,150
16,500	36,912	16,425-16,508	1,149
16,400	37,103	16,344-16,425	1,146
16,200	37,471	15,954-16,344	1,138
15,950	43,025	15,618-15,954	1,129
15,625	62,878	15,600-15,628	1,115
15,550	76,783	15,502-15,600	1,109
15,500	87,965	12,218-15,502	1,106
12,000	261,106	11,989-12,218	788
11,989	Infeasible		

TABLE 2. Water Demand Input-Output Results

Sector	IO Name	Water/FD[a]	GRP/FD[b]	GRP/AFT[c]
1	COTTON PRODUCTION	0.02392	0.52689	22028.3
2	FOOD GRAIN PRODUCTION	0.05446	0.53762	9872.3
3	FEED GRAIN PRODUCTION	0.11021	0.63488	5760.7
4	OIL BEARING CROPS	0.04622	0.87487	18926.6
5	TOBACCO	0.03121	0.89109	28552.7
6	LIVESTOCK &LIVESTOCK PROD.	0.99148	0.64467	650.2
7	OTHER AGRIC. PRODUCTION	0.05077	0.57564	11337.9
8	FORESTRY	0.01766	0.92518	52378.0
9	FISHERIES	0.00000	0.00000	0.0
10	AGRIC.,FORESTRY & FISHERIES	0.03249	0.56027	17246.6
11	IRON &FERROALLOY ORE MINES	0.00000	0.00000	0.0
12	NONFEROUS METALS MINING	0.00000	0.00000	0.0
13	COAL	0.00000	0.00000	0.0
14	CRUDE PETRO & NAT'L GAS EXT.	0.00000	0.00000	.
15	STONE & CLAY MINING	0.01328	0.63791	48038.8
16	CHEM. & FERTILIZER MINING	0.00000	0.00000	0.0
17	NEW CONSTRUCTION	0.01304	0.57445	44045.7
18	MAINTENANCE & REPAIR CONST.	0.00100	0.00000	0.0
19	ORDINANCE & ACCESSORIES MFG.	0.00000	0.00000	0.0
20	GRAIN MILL PRODS. MFG.	0.05431	0.52773	9717.2
21	BAKING PRODS. MFG.	0.03469	0.63588	18330.5
22	MISC. FOOD & KINDRED PROD. MF	0.19307	0.53940	2793.8
23	OTHER FOOD & KINDRED PROD.	0.02508	0.38022	15159.0
24	TOBACCO	0.00000	0.00000	0.0
25	BROAD-NARROW FABRICS-YARN-TD	0.05376	1.15353	21457.1
26	MISC. TEXTILE GOODS&FLOOR COV	0.02434	0.65869	27061.5
27	APPAREL	0.02697	1.01717	37718.6
28	MISC.FABRICATED TEXTILES	0.04588	1.37301	29924.3
29	LUMBER-WOOD PROD. MFG.	0.01548	0.66305	42843.4
30	FURNITURE & FIXTURES MFG.	0.01970	0.79432	40311.5
31	PAPER & ALLIED PRODS	0.00000	0.00000	0.0
32	PRINTING & PUBLISHING	0.01059	0.57689	54497.8
33	CHEMICALS MFG.	0.01087	0.44115	40596.8
34	PLASTICS & SYNTHETICS MFG.	0.01236	0.31181	25222.6
35	PETRO.REFINING & RELATED PRD	0.00361	0.11247	31120.2
36	RUBBER & MISC. PLASTICS PROD	0.01563	0.64484	41265.4
37	LEATHER, TANNING, ETC.	0.00000	0.00000	0.0
38	GLASS,STONE & CLAY PROD.MFG.	0.01435	0.59181	41240.6
39	PRIMARY METALS MFG.	0.00676	0.36394	53870.4
40	FABRICATED METALS MFG.	0.02630	0.52262	19874.3
41	MACHINERY,EXCEPT ELECTRICAL	0.01157	0.60831	52584.7
42	ELECTRICAL MACHINERY MFG.	0.02197	0.77345	35210.9
43	TRANSPORTATION EQUIP. MFG.	0.01217	0.58416	48002.2
44	SCIENTIFIC INSTRUMENTS MFG.	0.02113	0.95148	45020.5
45	MISCELLANEOUS MFG.	0.01054	0.50672	48089.3
46	TRANSPORTATION & WAREHOUSING	0.01217	0.67640	55571.1
47	COMMUNICATIONS	0.01369	0.76140	55623.6
48	UTILITIES	0.00957	0.55248	57700.1
49	WHOLESALE & RETAIL TRADE	0.02576	0.87076	33798.5
50	FINANCE, INSURANCE, REAL EST.	0.01489	0.80251	53900.7
51	HOTELS, LODGING PLACES	0.01390	0.69394	49930.8
52	BUSINESS SERVICES	0.01399	0.73084	52207.9
53	RESEARCH & DEVELOPMENT	0.00000	0.00000	0.0
54	AUTO REPAIR	0.01122	0.55046	49077.1
55	AMUSEMENTS	0.01688	0.63969	37901.5
56	MEDICAL,EDUC.,NON PROFIT SER	0.01683	0.76706	45582.1
57	FEDERAL GOV'T ENTERPRISES	0.01490	0.74495	50003.9
58	STATE & LOCAL GOV'T ENTERPR.	0.01106	0.57398	51894.2
59	GROSS IMPORTS	0.00000	0.00000	0.0
60	DUMMY ENTERPRISES	0.00000	0.00000	0.0
61	GOV'T (GENERAL)	0.00000	0.00000	0.0
62	REST OF WORLD	0.00000	0.00000	0.0
63	HOUSEHOLD INDUSTRIES	0.00000	0.00000	0.0
64	CONSUMERS	0.02332	1.37388	58914.5

[a] Water/FD = total water required (acre-feet) per thousand dollars of regional final demand.
[b] GRP/FD = gross regional product per dollar of exports.
[c] GRP/AFT = gross regional product per acre-foot of water required.
Source: Computed from Santee-Lynches Regional IO model and water use data.

native uses, several problems may be considered. First, the Y sector may be increased according to expected growth patterns among sectors until water does become an effective constraint to growth. Solving this problem requires also that the technical coefficient matrix w_i and l_i coefficients be forecasted.

As an alternative, we consider the problem of drought management, given the current technical structure of the region. The problem considered is to implement a water-use rationing scheme under emergency conditions in such a way as to maximize GRP under reduced water availability scenarios. Two alternative methods are considered to evaluate the relative value of water in alternative uses.

First, input-output sectoral water analyses procedures are used as described in equations (5) and (6). The ratio of gross regional product per dollar of final demand to water used per dollar of final demand (GRP/AFT) is listed for every sector in Table 2. This gives the current average ratio of GRP to water use for each sector. However, this is a poor guide to use in establishing the relative marginal value of water under drought conditions. These ratios are inadequate for drought management, because reducing the water available by one unit will have no effect on current output levels in this region (i.e., its shadow price is zero).

The second procedure used is the combined IOLP model. We solved for optimal sector output levels (to maximize GRP) under four alternative W_o constraints: 45,168; 44,148; 17,200; and 16,200 acre-feet. As shown in Table 1, the shadow price of value is about \$700/acre-foot at the upper range of W_o. To estimate the value of water in alternative uses within this range, solutions to the IOLP model were obtained when W_o was equal to 45,168 (OUTPUT 1) and 44,148 (OUTPUT 2). The change in output in each sector is computed as the difference (DIF12) between OUTPUT 1 and OUTPUT 2. Thus, DIF12 is the value of 1000 acre-feet of water to GRP when the shadow price is \$700. Similarly, DIF34 is the difference between the output solutions to the IOLP model when W_o varies from 17,200 to 16,200 acre-feet (OUTPUT 3-OUTPUT 4) and the shadow price varies from \$8,000 to \$37,000. Table 3 lists DIF12, DIF34, and the input-output solution, along with the rankings of each of the 64 sectors under each solution.

The results in Table 3 provide a basis for valuing water among competing users. The DIF12 column gives the desired increase in output for each sector in order to maximize GRP, as the level of water available increases by 1000 acre-feet, starting from the 44,148 acre-feet level. To obtain this result, water could be allocated to each of the 64 sectors by using the w_i coefficients and the X_i value from the DIF12 column. Similarly, when the level of water available falls to 16,200 acre-feet and an additional 1000 acre-feet becomes available, DIF34 X_i values could be used in the same way.

This analysis shows that when water availability is increased from 44,148 acre-feet to 45,148 acre-feet, several of the agricultural sectors are primary beneficiaries. The top-ranking non-household sectors are livestock and livestock products (sector 6), feed grains (sector 3), trade (sector 49), and miscellaneous food and allied products (sector 22).

This situation corresponds approximately to the 1980 level of water usage within the Santee-Lynches COG region. In the event that water is deemed to be in short supply, in the near term, it is likely that these sectors would most benefit the region as additional water became available. Likewise, any reduction in their water allocation would likely have the largest negative impact on regional income.

The DIF34 column presents the results of a situation with exceptionally low water supply. In this situation, the water available is set at 17,200 acre-feet, with the shadow price of \$7,934. Reducing the supply by a thousand acre-feet to 16,200 sharply increases the shadow price of an additional unit of water to \$37,471. The non-household sectors whose output changes the greatest are fabricated metals manufacturing (sector 40), miscellaneous food and kindred products manufacturing (sector 22), other food and kindred products (sector 23), and wholesale and retail trade (sector 49). It is interesting to note that at this level of water availability, there are no agricultural sectors represented in the top five sectors most sensitive to the decrease in water availability. However, oil-bearing crops (sector 4) improved its rank from 27th (DIF12 column) to 7th. Cotton (sector 1) also improved its rank position (42nd to 14th), while livestock (sector 6) falls from 1st to 55th.

For the agricultural sectors, given the interdependencies within the local economy and current water-use coefficients, the major implications of the analysis are that water resources will yield the highest GRP, in times of severe drought, if soybean and cotton production increase relative to livestock production.[3] Of course, with changing irrigation practices, the composition of the manufacturing sector (high versus low water-intensive sectors) can affect the water use coefficients and the resulting ranking of each sector.

Assuming that there is no change from current

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[3] A key assumption is that the farm sectors as well as other sectors will continue to use the same quantity of water per dollar of output under drought condition as they are using under the current conditions of excess water availability. However, one *Journal* reviewer indicated that producers are likely to respond to drought conditions by varying their input structure to reduce water use. Although it is not known to what extent this reduction in the water-use coefficients could or would occur, there is little doubt that water conservation would occur if water resources were valued according to some pricing mechanism that reflects the marginal value product of water.

TABLE 3. Value of Water by Sector of Use in the Santee-Lynches, SC Region

		Value in Dollars					
SECTOR	IO Name	DIF12[1]	DIF34[2]	IO[3]	RANK1[4]	RANK2[5]	RANK3[6]
1	COTTON PRODUCTION	821	616824	22028	42	16	35
2	FOOD GRAIN PRODUCTION	5804	174762	9872	19	29	43
3	FEED GRAIN PRODUCTION	354583	1198069	5761	3	12	45
4	OIL BEARING CROPS	2887	3931222	18927	27	7	38
5	TOBACCO	0	0	28553	55	55	32
6	LIVESTOCK &LIVESTOCK PROD.	1204406	0	650	1	55	47
7	OTHER AGRIC. PRODUCTION	2774	424833	11338	29	18	42
8	FORESTRY	1138	37074	52378	41	40	9
9	FISHERIES	0	0	0	55	55	56
10	AGRIC.,FORESTRY & FISHERIES	52364	305225	17247	7	24	40
11	IRON &FERROALLOY ORE MINES	0	0	0	55	55	56
12	NONFEROUS METALS MINING	0	0	0	55	55	56
13	COAL	0	0	0	55	55	56
14	CRUDE PETRO & NAT'L GAS EXT.	0	0	0	55	55	56
15	STONE & CLAY MINING	1797	29454	48039	36	41	16
16	CHEM. & FERTILIZER MINING	0	0	0	55	55	56
17	NEW CONSTRUCTION	0	0	44046	55	55	20
18	MAINTENANCE & REPAIR CONST.	0	0	0	55	55	56
19	ORDINANCE & ACCESSORIES MFG.	0	0	0	55	55	56
20	GRAIN MILL PRODS. MFG.	8403	413115	9717	16	19	44
21	BAKING PRODS. MFG.	150	6668	18330	44	44	39
22	MISC. FOOD & KINDRED PROD. MF	98693	9915086	2794	5	3	46
23	OTHER FOOD & KINDRED PROD.	4738	8049647	15159	21	4	41
24	TOBACCO	0	0	0	55	55	56
25	BROAD-NARROW FABRICS-YARN-TD	6683	6789202	21457	18	5	36
26	MISC. TEXTILE GOODS&FLOOR COV	1249	54338	27061	39	39	33
27	APPAREL	19313	788133	37719	11	14	27
28	MISC.FABRICATED TEXTILES	1666	75849	29924	37	37	31
29	LUMBER-WOOD PROD. MFG.	2465	286590	42843	31	25	21
30	FURNITURE & FIXTURES MFG.	4223	168144	40311	25	30	25
31	PAPER & ALLIED PRODS	0	0	0	55	55	56
32	PRINTING & PUBLISHING	2073	135755	54498	33	33	5
33	CHEMICALS MFG.	9227	400232	40597	14	20	24
34	PLASTICS & SYNTHETICS MFG.	4573	2836476	25223	23	8	34
35	PETRO.REFINING & RELATED PRD	1166	28827	31120	40	42	30
36	RUBBER & MISC. PLASTICS PROD	2631	393737	41265	30	21	22
37	LEATHER, TANNING, ETC.	0	0	0	55	55	56
38	GLASS,STONE & CLAY PROD.MFG.	2027	276383	41241	35	26	23
39	PRIMARY METALS MFG.	130	183141	53870	45	28	7
40	FABRICATED METALS MFG.	6813	22768171	19874	17	2	37
41	MACHINERY,EXCEPT ELECTRICAL	356	22683	52585	43	43	8
42	ELECTRICAL MACHINERY MFG.	13245	629233	35211	13	15	28
43	TRANSPORTATION EQUIP. MFG.	2131	82900	48002	32	36	17
44	SCIENTIFIC INSTRUMENTS MFG.	2800	157327	45021	28	32	19
45	MISCELLANEOUS MFG.	1378	56972	48089	38	38	15
46	TRANSPORTATION & WAREHOUSING	8813	376550	55571	15	22	4
47	COMMUNICATIONS	14700	539052	55624	12	17	3
48	UTILITIES	32574	1239576	57700	9	11	2
49	WHOLESALE & RETAIL TRADE	151329	5751699	33798	4	6	29
50	FINANCE, INSURANCE, REAL EST.	45472	1356679	53901	8	10	6
51	HOTELS, LODGING PLACES	21822	1003754	49931	10	13	13
52	BUSINESS SERVICES	5492	328877	52208	20	23	10
53	RESEARCH & DEVELOPMENT	0	0	0	55	55	56
54	AUTO REPAIR	4679	161296	49077	22	31	14
55	AMUSEMENTS	2967	118029	37902	26	34	26
56	MEDICAL,EDUC.,NON PROFIT SER	72738	2618101	45582	6	9	18
57	FEDERAL GOV'T ENTERPRISES	4487	208486	50004	24	27	12
58	STATE & LOCAL GOV'T ENTERPR.	2043	84967	51894	34	35	11
59	GROSS IMPORTS	0	0	0	55	55	56
60	DUMMY ENTERPRISES	0	0	0	55	55	56
61	GOV'T (GENERAL)	0	0	0	55	55	56
62	REST OF WORLD	0	0	0	55	55	56
63	HOUSEHOLD INDUSTRIES	0	0	0	55	55	56
64	CONSUMERS	650149	25726004	58915	2	1	1

[1] The change in output resulting from an increase in water availability from 44148 acre-feet to 45148
[2] The change in output resulting from an increase in water availability from 16200 acre-feet to 17200
[3] The average output per acre-foot of water as determined by the IO model (see Table 2)
[4] The rank by magnitude of the change shown in DIF12
[5] The rank by magnitude of the change shown in DIF34
[6] The rank by magnitude of average output per acre-foot of water shown in IO
Source: See Table 2.

irrigation practices in the region, we can draw several conclusions from our results regarding competition for water within agriculture and between agriculture and other sectors. Looking at agriculture first, we find that with adequate water, the livestock and feed grains sectors would make the greatest contribution to GRP from additional water supplies in the region. However, if water is in short supply, then livestock is no longer desirable, and among the agricultural sectors, a shift to soybeans would most improve the region's GRP. There are two reasons for this shift. First, livestock contributes more to GRP directly and indirectly than soybeans, when water is not an important limiting factor. Second, livestock requires more direct and indirect water

inputs per dollar of final sales than do soybeans, and as water becomes increasingly scarce, this facet of soybean production becomes more important to incremental GRP growth than do the larger value-added aspects of livestock production.

Next we find that, with adequate water supplies, livestock and feed grains are the top-ranking nonhousehold sectors. Accordingly, additional water allocations to these agricultural sectors are clearly justified from a GRP perspective, given current irrigation practices in the region. Even in periods of short supply, the soybean sector and feed grain sectors rank among the top 15 sectors in contribution to GRP from additional water resources availability. Thus, if water resources become scarce in the region, agriculture can continue to compete effectively with other sectors for water resources by real-locating its resources into oil-bearing crops and away from livestock.[4]

Data in Table 3 imply that the relative value of water to the region in alternative use depends on the estimating technique used and on the *level* of water available. Use of the IO technique results in sector rankings that reflect current average GRP generated per acre-foot of water used. The agricultural sectors (1 through 7) generally rank very low in terms of this average measure. This is an inappropriate water valuation methodology for this region, given the current abundance of water relative to the aggregate demand for water.

On the other hand, the IOLP model yields appropriate measures of relative water value between sectors under conditions where the water shadow price is nonzero. These conditions may prevail in the face of short-term drought conditions or as future growth increases the aggregate demand for water resources.

DATA PROBLEMS

The IOLP model offers a basis upon which to analyze water supply and distribution issues. However, it is not without major shortcomings. The most important of these is the problem of data. The construction of an input-output model requires massive amounts of data. The non-survey technique used in creating the Santee-Lynches model fortunately provided an acceptable alternative; however, the large degree of in-

dexing required to update the model was far from ideal.

Water-use data are also not readily available for all sectors. In fact the water used in agriculture may be slightly underestimated, because it is probable that farmers who use irrigation are likely to overwater once the system is in operation. As the need for improved data on water use is realized by both manufacturing and agriculture and advances are made in this area, economic analysis relating to water will become more reliable and precise.

SUMMARY AND CONCLUSIONS

This study has shown how an input-output model and linear programing can be combined to create a useful tool for water resource planning. The need for such a tool, capable of determining the marginal value of water to different uses, stems from the lack of a viable market mechanism for water. With regional growth and increased agricultural demands for water a reasonable likelihood, competing demands on water could conceivably result in inefficiencies in water allocation and suboptimal incomes for the region. While some contend that the proper approach to solving our water problem is through explicit ownership, rather than by a system of government allocations, political and social difficulties render their proposal to a status of long-term institutional evolution. Moreover, there are very few a priori grounds for judging to what extent a free market would transfer water between sectors of a regional economy. It is an empirical question for specific situations. Therefore, the model presented in this study offers an empirical basis upon which to establish an allocation scheme.

The empirical results of this study make possible several specific conclusions uniquely valid for the Santee-Lynches region. The first and most obvious is that the Santee-Lynches region as a whole can experience significant growth without water becoming a formidable constraint. However, additional delivery systems will be needed if growth continues into the long term. A second conclusion relates specifically to the agricultural sectors. The evidence suggests that as water becomes constraining, a movement

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[4] This conclusion regarding agriculture's ability to compete effectively for water resources must be tempered with some results from model runs that used revised water-use coefficients for the agricultural sectors.

We investigated the sensitivity of the model results to changes in irrigation patterns by estimating a second set of w_i coefficients for the agricultural sectors. We assumed that all farms would irrigate using water at the same rate as farms currently irrigating in the region.

The model was run for the case of low water supply with high agricultural water demand. The results reflect a stituation where there was universal adoption of irrigation with no expansion of current water systems. Using a base supply of 66,628 acre-feet, a reduction to 65,628 acre-feet borders on infeasibility. The model results indicate that for the agricultural sectors, cotton production and livestock production should be drastically reduced.

The highest ranking manufacturing sectors are miscellaneous food products (sector 22), apparel (sector 27), electrical machinery (sector 42), broad and narrow fabric (sector 25), furniture and fixtures (sector 30), and plastics and synthetics (sector 34). These manufacturing sectors, and three others, 32, 33, and 36, all rank higher than the highest agricultural sector, oil-bearing crops (sector 4). Under this situation, the highest ranking sectors are in the trade and service sectors. Their low water use coefficients indicate that they use little water in relation to the value of their output. With water at such limiting levels, encouragement of these sectors would be highly beneficial in increasing gross regional product.

away from the production of livestock and toward increased production of soybeans will be advisable. A third conclusion is that in terms of the marginal value of sectoral output as water availability changes, the food and kindred products manufacturing sector is consistently a primary asset in contributing to regional income under water-constrained situations. A final conclusion is that some agricultural sectors compete effectively for water even under severe water-constrained situations, given current irrigation practice in the region.

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