Water: Its Changing Role in U.S. Agriculture

by

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The interrelationship between food security of the United States and a diminishing water resource balances on the condition of that water resource, the quantity of other substitute resources, and the level of future technology. The answer to whether food supplies in the United States can be threatened by a given resource such as water cannot be answered solely by examining the resource in question. Rather the interactions of all resources used in the production of agricultural commodities must be analyzed.

In the recent past, the United States has had an abundance of land with yields increasing faster than demands. With real commodity prices, for the most part, decreasing over the past century, supply control programs have been initiated so that price supports are gained.

On the other side of the ledger, embargos have been placed on agricultural commodities when domestic food prices spiral upwards (1973-1974 period for instance). Weather conditions have at times dampened yields. The quality of presently unused inputs, such as land, does not seem as good as what is already in production.

A glance over the past two decades of agricultural history yields some interesting observations. The 1960s were characterized by chronic surpluses in most nonperishable agricultural commodities. Various land retirement programs were in evidence. As much as 63 million cropland acres were withheld from production during the 60s.

The turn of the decade, however, brought about reduced supplies, increased input costs, and higher commodity prices. During the early to mid-70s, world grain production greatly fluctuated. A world food crisis began. The United States called upon the farmers to plant fence row to fence row. Experts were predicting famine for much of the less developed world (Cochrane, 1979). In the space of five years (1969-1974), the United States nearly doubled their wheat exports. Farmers responded to the increased worldwide demands by dramatically increasing production.

The water resource played an important role in this change. Wells were sunk in the Great Plains. Previously unproductive lands became extremely productive as water became available.

Since this time, much concern has been expressed as to resource availability, technological development, and resource quality. Attempts are being made to analyze whether the United States has the resources available to meet future agricultural demands (both domestic and export). Water availability and quality are both being studied.

Water Supply and Demand

In the long run, the consumption of water must be less than or equal to the supply of water. In 1975, the United States withdrew 338 billion gallons per day of fresh water (both surface and ground) for such offstream uses as agriculture, manufacturing, etc. By the year 2000, this amount is projected to decrease to 306 billion gallons per day or a 9 percent reduction. This decline in water demand will be caused primarily by a more efficient use of water (U.S. Water Resources Council, 1978). On the supply side, an average of 40,000 billion gallons per day of water passes over the United States in the form of water vapor. Approximately 10 percent or (4,200 billion gallons per day) falls as precipitation. Nearly two-thirds of this precipitation evaporates immediately or is transpired by vegetation. Thus, 1,450 billion gallons per day accumulates in ground and surface storage, flows to the oceans or into Mexico or Canada, is consumptively used, or evaporates from reservoirs. Only 675 billion gallons per day can be considered as a reliable water supply (U.S. Water Resource Council, 1978).

From these nationwide figures, one would conclude that the reliable supply exceeds projected demand by a good margin. However, regionally this is not the case. An estimated 392.8 billion gallons per day were withdrawn to meet 1975 water demands with 81.2 and 254.2 billion gallons per day coming from ground and surface supply sources, respectively (Table 1). Over 20 percent of the groundwater used in the Missouri (24.6 percent), Arkansas-White-Red (61.7 percent), Texas-Gulf (77.2 percent), Rio Grande (28.1 percent), Lower Colorado (48.2 percent), the Great Basin (41.5 percent) water resource regions result from groundwater mining. Thus, in these regions, supply is less than demand at the present time.

As of yet, little has been attributed to agricultural reliance on water. It is estimated that 68 percent of the groundwater withdrawn and 35 percent of all water is used for irrigation. Table 2 shows that withdrawals of water are assumed to decline between 1985 and 2000 by nearly 12 million gallons per day with many of the river basins in the western United States reflecting a decline in water withdrawn.

Table 1. Water withdrawn by source and percent of groundwater overdraft by water resource region, 1975

Water resource region	Ground total withdrawn	Overdraft[a]	Surface total withdrawn	Total withdrawn[b]
	(mgd)[c]	(percent)	(mgd)	(mgd)
New England	635	0	4,463	10,314
Mid-Atlantic	2,661	1.2	15,639	37,925
South Atlantic	5,449	6.2	19,061	31,970
Great Lakes	1,215	2.2	41,598	42,813
Ohio	1,843	0	35,091	34,934
Tennessee	271	0	7,141	7,416
Upper Mississippi	2,366	0	10,035	12,401
Lower Mississippi	4,838	8.5	9,729	15,820
Souris-Red-Rainy	86	0	250	336
Missouri	10,407	24.6	27,609	38,016
Arkansas-White-Red	8,846	61.7	4,022	12,868
Texas-Gulf	7,222	77.2	9,703	26,088
Rio Grande	2,335	28.1	3,986	6,321
Upper Colorado	126	0	6,743	6,869
Lower Colorado	5,008	48.2	3,909	8,917
Great Basin	1,424	41.5	6,567	7,991
Pacific Northwest	7,348	8.5	30,147	37,626
California	19,160	11.5	20,476	54,705
	81,240	25.0	254,169	392,826

[a] Overdraft/total withdrawn *100

[b] Includes water from saline sources
Source: [U.S. Water Resources Council, 1978]

[c] Million gallons per day.

Table 2. Projected irrigation withdrawal and consumption by water resource region, 1985 and 2000 [a]

Water resource region	Withdrawal 1985	Withdrawal 2000	Consumption 1985	Consumption 2000
	- - - - (million gallons per day) - - - -			
New England	41	46	29	33
Mid-Atlantic	366	481	269	354
South Atlantic	4,008	4,509	3,184	3,597
Great Lakes	211	282	169	232
Ohio	68	91	53	74
Tennessee	18	21	14	17
Upper Mississippi	283	387	230	323
Lower Mississippi	4,559	4,444	3,204	3,272
Souris-Red-Rainy	144	434	116	350
Missouri	39,376	36,236	17,597	17,607
Arkansas-White-Red	10,483	9,776	7,468	7,125
Texas-Gulf	9,333	7,427	7,597	6,100
Rio Grande	5,498	4,873	3,920	3,570
Upper Colorado	7,223	6,672	2,657	2,741
Lower Colorado	7,299	6,343	3,962	3,720
Great Basin	6,120	5,825	3,082	3,196
Pacific Northwest	34,639	29,961	13,362	13,213
California	34,863	34,764	25,134	26,311
	164,532	152,572	92,047	91,835

[a] Source: (U.S. Water Resource Council, 1978).

The volume of groundwater greatly exceeds surface runoff, however, the increasing demands on this resource are straining the supply. Groundwater mining is occurring in the Ogallala Aquifer from Nebraska to Texas, in south-central Arizona and parts of California.

As water tables decline, energy costs for pumping increases. Real energy prices in the past decade and in the foreseeable future have and will increase. These real energy price increases along with declining water tables will influence the quantity of water that can be economically pumped. Before this occurs, alternative sources of water must be found, artificial recharge methods must be developed, water using activities must be relocated, and/or water use must be reduced through conservation and improvement of managerial techniques. The U.S. Water Resources Council's assessment (1978) indicates that the potential savings in irrigation withdrawals range between 30 and 45 billion gallons per day. This can be achieved by lining and/or covering canals, monitoring and scheduling of water release using the computer, and other technological advances. Applying these technologies is estimated to increase efficiciency 10 percent in moving waters from the source to the field. On-farm efficiencies are estimated to range between 10 and 40 percent. These technologies include closer scheduling of water application in meeting crop needs, irrigating at night, improving the irrigation system, and preparing the land better.

However, these increased efficiencies will not significantly decrease the amount of mining that currently occurs. The Interagency Task Force (1979) stated that only about 15 percent of the current groundwater mining would disappear if the Soil Conservation Service's accelerated water conservation programs were implemented. Thus, other methods of conservation, such as capturing water before it becomes runoff, increasing the levels of snow management, and controlling undesired vegetation along waterways will have to be undertaken if water use levels are to be maintained.

Examination of Some Future Assumptions

Even though we are certain that the supply of water for agriculture in the United States will decline over the next three decades due to increased pumping costs (because of lowered water levels and higher energy costs) and increased competition with other water users, we can best dampen the impact of declining water supplies through a vigorous R&D program which meshes the corrosponding resource scarcities and prices and technologies which can substitute for them.

In examining how critical water is in meeting national food demands, it would be useful if we could select specific future dates, set all of the exogenous and some of the endogenous variables, vary water supplies, and predict the resulting expected increases in commodity prices. Statistical, econometric, and other methods or models for these predictions do not exist, nor will they in the near future. Changes in the variables and institutions that affect water supplies and demand may change gradually or dramatically (i.e., the 1974 energy shortage). Meanwhile, these types of changes do not exist in historical data, so we cannot use the past to statistically predict the future impacts.

For some years, economists at the Center for Agricultural and Rural Development (CARD) have incorporated both ground and surface water sectors into large-scale interregional programming models of U.S. agriculture. This modeling technique does not attempt to predict, rather, it examines what should occur. Generally, these models have examined alternative demand levels, examined increasing real water prices, considered trend and other levels of yield improvement over time, allowed land not currently in crops to be transferred to cropland, and studied the impacts of alternative water price levels. These variables provide the means by which projections can be made as to the potential changes in regional and national production and resource use in agriculture. An analysis can be conducted as the national as well as regional importance of the water resource required to meet national demands. Finally, a means of studying resource abundance and resource scarcity can be conducted.

Recently, a set of models were analyzed for the Soil and Water Resources Conservation Act (RCA). The level of exports, the level of technological change assumed, and the amount of land incorporated in the model are the primary factors in determining the ability of the nation to meet production goals. The models determining the quantity of water and its marginal price as the above factors are allowed to vary.

In the RCA, the two major resources of concern to agriculture are land and water. The natural resource land is covered elsewhere in this book. Suffice it to say that the Soil Conservation Service (SCS) has estimated that there are 127 million acres of high or moderate range and forest land that could be converted to cropland. Thus, an additional increase of 30 percent in the cropland base could occur in the future. This land is not presently available for conservation due to economic, physical, and sociological factors. However, over a long-run time frame of 20 to 50 years, these factors tend to change.

Based on current existing technology, by the year 2000, wheat yields could increase by 50 percent, soybean yields by 60 and corn by 40 percent.

Over the same time frame, the amount of production gains per breeding female is predicted to increase 25 percent for beef, pork, and dairy products [English, Maetzold, Holding, and Heady, 1983]. These estimates are mugh higher than the "moderate" technology scenario used in the 1980 Soil and Water Resources Conservation Act analysis.[1]

Given these data, land does not appear to be a scarce resource and the notion of production plateaus cannot be supported. Thus, it would seem that demand levels would determine whether water will be a scarce enough resource over the long run to threaten the nation's food supply. However, several land estimates and technology levels are used in the RCA analysis.

An agricultural programming model assuming projected demands and yields for 2030 is in conjunction with the estimated quantity of resources available is used in the RCA analysis. In the 2030 CARD-RCA model, a set of shadow prices is generated.[2] These shadow prices suggest that a general interaction among these variables exist. An index for required water use and the related shadow prices is presented in Table 3 for a) a base-1 solution (BASE-I) which assumes a 380 million acre cropland base, b) a base-2 solution (BASE-II) which allows an additional 127 million acres identified by the SCS as having the potential of conversion, c) a high technology

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[1] This scenario assumed 1.1 percent per year productivity gain by the year 2000 as the most likely alternative.

[2] Shadow prices refer to the cost of producing the last unit. Hence, it is a marginal cost concept. It is a set of crop prices which indicate what the producer must receive if the assumed demand is to be met.

Table 3. Indices of selected variables for five different scenarios 2030

Variable	BASE-I	BASE-II	III	IV	V
Water Use	100	91	65	109	210
		(100)[a]	(71)	(120)	(231)
			[100][b]		[323]
Water Shadow Price	100	63	44	63	280
		(100)	(70)	(100)	(444)
			[100]		[636]
Corn Price	100	50	37	64	167
		(100)	(74)	(128)	(334)
			[100]		[451]
Wheat Price	100	64	54	74	176
		(100)	(84)	(116)	(275)
			[100]		[326]
Soybean Price	100	71	58	59	179
		(100)	(82)	(83)	(252)
			[100]		[309]
Cotton Price	100	70	71	77	139
		(100)	(101)	(110)	(199)
			[100]		[196]

[a] ( ) compares the technology solution (III, IV, V) to BASE-II

[b] [ ] compares solution V to III with demand levels as the only item that is changing.

scenario with the increased land base (III), d) a low technology scenario with the increased land base (IV), and e) a maximum production scenario assuming a high technology level and increased land base.

The figures indicate that if technology continues to increase as is reflected by the past, and that 127 million acres of land is available for commodity production, water use would decline by 10 percent with the water value[1] declining by 37 percent and commodity shadow prices[2] decreasing 50, 36, 29, and 30 percent for corn, wheat, soybean, and cotton, respectively. Assuming high technology and an additional 127 million acres of cropland (III), a 29 percent decrease in the quantity of water used and a 30 percent decline in the value of water is projected to take place when compared to BASE-II. If the technology levels are lower than the BASE-II levels, an increase in water use of 20 percent is projected but the value of water does not change at all when compared to BASE-II. The production capacity in IV is still great enough so that the marginal value of water is similar to the BASE-II solution. However, if the water supplies were reduced below this level, one should expect the commodity shadow prices to move upward considerably and eventually exceed the shadow prices reflected in the BASE-I solution.

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[1] Water value is determined from a shadow price resulting from a programming model that is specified so that the given alternatives can be examined. The prices of water indicate the value of water, at the margin, to produce the nation's output under the combination of conditions outlined.

[2] The supply prices for the commodities show the levels necessary to attain the prescribed level of production under the resource and technology conditions analyzed.

The demand level, also, influences the levels of change that these variables undertake. The maximum production alternative examines the production potential of this nation assuming a high level of technology along with the 507 million acre cropland base. To fully use this land and to maximize production, water use would increase 223 percent from III and 110 percent from BASE-I. An increase of 280 percent in the water shadow price is projected when this solution is compared to BASE-I with commodity shadow prices increasing an average of 70 percent. These higher prices result from the increased production level, complete use of the available land, and greater demand on the water resource. If this amount of water available in 2030 is reduced, commodity prices would increase, or the nation may not be able to meet the prescribed production levels.

Another assumption that one must examine when determining whether water will be a critical resource in meeting the nation's food and fiber demand is the impact of prices of that input on the nation's ability to produce. The "market" price of surface water, historically, has not been subject to normal market forces because of publicly subsidized rates. Recently, however, some of the water previously used for agriculture has been purchased by users and market transfers have taken place. However, the observations and data base of these transfers is so incomplete that statistical estimation of a water demand function that incorporates commodity supplies and prices as well as resource or input prices is currently impossible. Thus, it seems that a normative analysis of the demand for ground and surface water is the only means for evaluating the national impacts incurred due to increased water prices. A normative study was undertaken by Christensen, Morton, and Heady (1981) set prices for ground and surface water at farm levels for each with the initial price of surface water equaling the 1975 Bureau of Reclamation costs and the price of groundwater being estimated by the 1975 pumping costs plus 15 percent of the fuel costs for maintenance [Dvoskin, Heady, and English, 1978]. These costs or prices were then doubled (SW2, GW2), tripled (SW3, GW3), and quadrupled (SW4, GW4), so that 16 price combinations were derived (Figure 1). The normative water demand responses indicate the level of water demanded for each set of prices.

Relative to the base solution (GW1, SW1), water use decreases from 50.5 to 24.7 million acre-feet for endogenous crop and livestock production when both ground and surface water prices are quadrupled. While water use declines by 50 percent, very little impact on commodity prices is projected (Table 4).

Conclusions

It is inadequate to simply study the supply and demand for water in a localized area when examining food security of the United States. Numerous resources are used in the production of agricultural commodities. The resources serve, at least at a national perspective, as substitutes. As one becomes limiting, more of another is used.

As agriculture approaches production capacity, changes in the prices of a resource, or a reduction in the quantity of the resource will have

Groundwater Prices →

Surface Water Prices ↓

GW1SW1	GW2SW1	GW3SW1	GW4SW1
GW1SW2	GW2SW2	GW3SW2	GW4SW2
GW1SW3	GW2SW3	GW3SW3	GW4SW3
GW1SW4	GW2SW4	GW3SW4	GW4SW4

Figure 1. The 4 by 4 alternative price matrix

Table 4. Indices of selected variables under four price combinations for water

Item	Water Price Levels GW1SW1	GW2SW2	GW3SW3	GW4SW4
Groundwater use	100	59	46	44
Surface water use	100	85	65	51
Corn shadow price	100	100	100	105
Wheat shadow price	100	104	106	110
Soybean shadow price	100	102	103	105
Pork shadow price	100	102	103	105
Beef shadow price	100	103	104	106

a larger impact on the nation's ability to produce the necessary commodities if some resources are being left idle. It would appear that given 127 million acres of potentially available cropland, changes in levels of technology not less than that experienced in the past, and modest exports, water is not an input whose scarcity will impact on the food security of the United States.

It is entirely conceivable that the long-run aggregate agricultural commodity supply function is of the following nature:

> "Over some range, it may remain highly elastic as opportunities remain to convert more land to crops and to further adjust the allocation and technology of water use. But eventually, with complete use of all potential cropland which can be converted at reasonable costs, higher prices and smaller supplies of water and exhaustion of reallocation possibilities for water, the supply elasticity may decline greatly with a sharp upturn in the commodity supply function" [Heady, 1982, p. 22]

Many scientists would argue that this point has already been reached and that the corner has been turned. Under this scenario, the major agricultural problem of the future will be how can we produce more at reasonable prices. However, given our recent experiences, characterized by large crops and low commodity prices, others will argue that the corner has not been turned and we are still in the elastic portion of the supply function. Supplemental irrigation techniques, double cropping, land conversion, etc., all act as substitutes for scarce resources such as water. Even within the scarce resources, substitutes or increases in efficient use of the resource can be found. As the price of water increases due to diminished supply and greater demands, more incentive will exist to make more efficient use of this resource. Little evidence can indicate that this corner has been turned. The substitutes available in agriculture still are present in great quantities.

However, the impact of declining water tables can have severe regional consequences. Regions forced to dryland farming as the water situation changes will be looking at a reduced output but little price increase. Hence, revenues will decline. As revenues decline communities serving these agricultural areas will be affected and hardships placed upon them.

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