Chapter 2.1

Irrigation Resources and Water Costs

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Irrigated agriculture remains the dominant use of freshwater in the United States, although its share of use is declining. Irrigated cropland area has expanded over 40 percent since 1969, while water application rates have declined about 20 percent. The total quantity of irrigation water applied increased about 10 percent since 1969. Nationally, the average variable cost of supplying water for irrigation was about $50 per acre in 2003; however, that amount does not reflect the full value of water.

Introduction

The United States, as a whole, has abundant freshwater supplies. Annual renewable supplies in surface streams and aquifers total roughly 1,500 million acre-feet per year (maf/yr). (See the "Irrigation and Water Use" Briefing Room on the ERS website) for definitions. Of total renewable supplies, only one-quarter is withdrawn for use in homes, farms, and industry, and just 7 percent is actually used, i.e., lost to the immediate water environment (Moody, 1993). Roughly 90 percent of total water use nationwide comes from renewable surface- and ground-water supplies. The remainder comes from depletion of stored ground water (Foxworthy and Moody, 1986).

An abundance of water in the aggregate belies increasingly limited water supplies in many areas, reflecting the uneven distribution of the Nation's water resources. In the arid West, more than half of the renewable water supplies are consumed under normal precipitation conditions. In drought years, water use often exceeds renewable flow through the increased use of water stored in aquifers and reservoirs. While droughts exacerbate supply scarcity, water demands continue to expand with resulting reallocations among uses. Urban growth, for example, has greatly expanded municipal water demands in arid areas of the Southwest and far West. At the same time, demand for instream (nonconsumptive) water flows for recreation, riparian habitat, and other environmental purposes has heightened competition for available water supplies in all but the wettest years. While future water needs for instream uses are difficult to quantify, the potential demands on existing water supplies are large and geographically diverse.

Historically, increased water demands were met by expanding available water supplies. Dam construction, groundwater pumping, and interbasin conveyance provided the water to meet growing urban and agricultural needs. However, future opportunities for large-scale expansion of seasonally reliable water supplies are limited due to lack of suitable project sites, limited funding, and increased public concern for environmental consequences. Future water demands will increasingly be met through realloca-

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tion of existing supplies. Since agriculture is the largest freshwater user, reallocation will likely reduce supplies for agriculture (National Research Council, 1996). Changes in agricultural water availability may have significant impacts on irrigation-dependent crops in some locations, with implications for local agricultural industries and rural communities.

Agricultural Water Withdrawals

Freshwater withdrawals—the quantity of water diverted from surface- and ground-water sources—totaled 387 million acre-feet (maf) in 2000 (fig. 2.1.1). Agriculture (159 maf) and thermoelectric power generation (152 maf) dominate withdrawals, with domestic and commercial water supplies, industry, and mining withdrawing a combined 75 maf (Hutson et al., 2004).

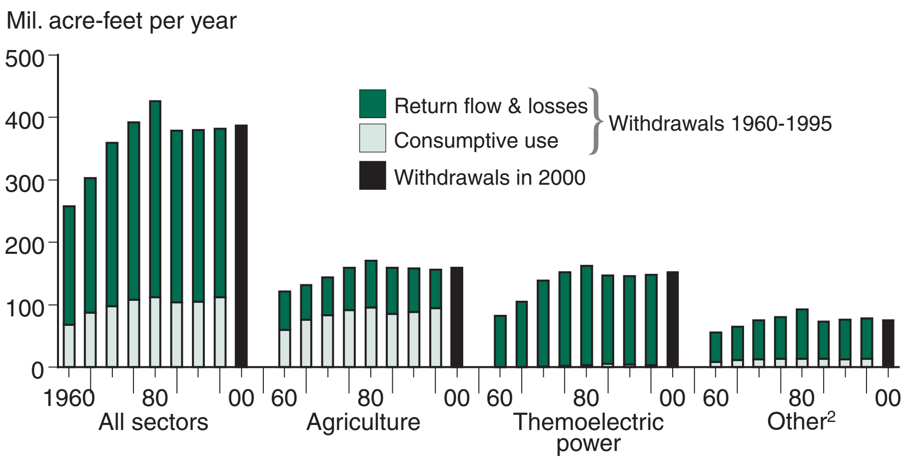
Agricultural withdrawals as a share of U.S. freshwater withdrawals declined from 46 percent in 1960 to 41 percent in 2000.[1] Thermoelectric power generation increased its share from 32 to 39 percent over the same period. Water withdrawals are not the only measure of water use. Consumptive use—the water not returned to the immediate water environment—is much greater for agriculture than any other sector, both in total and as a share of water withdrawn. Estimates available from 1960 through 1995 show that agriculture accounts for over 80 percent of the Nation's consumptive use (fig 2.1.1), because a high share of applied irrigation water is used by plants for evapotranspiration, with little returning to surface or ground water. (Water diverted for cooling thermoelectric plants tends to be used as a thermal sink, with much of it returned to rivers and streams.) Greater irrigation withdrawals do not necessarily translate into greater consumptive use per irrigated acre. The difference between withdrawals and consumptive use highlights the importance of losses, runoff, and return flows.

[1]The irrigation component of the withdrawal estimates by Hutson et al. are primarily agricultural (cropland and pastureland), but also include recreational area irrigation (parks and golf courses).

Most agricultural water withdrawals occur in the arid Western States where irrigated production is concentrated. In 2000, about 85 percent of total agricul-

Figure 2.1.1

Water withdrawals in 2000 and withdrawals with consumptive use estimates, 1960-1995[1]



[1]Data limitations do not allow estimation of consumptive use in 2000.
[2]Includes public supplies, domestic supplies and industry, except power generation.

Source: USDA, ERS, based on Hutson et al., 2004.

tural withdrawals occurred in a 19-State area encompassing the Plains, Mountain, and Pacific regions (table 2.1.1). In the Mountain region, over 90 percent of the water withdrawn is used by agriculture, almost all (96 percent) for irrigation. Nationally, irrigation is the dominant agricultural water use, but water withdrawn for livestock and aquaculture production (including fish hatcheries) accounts for almost 20 percent of withdrawals in the North-Central and Eastern States. Even in these more humid States, irrigation is the dominant agricultural water use.

Surface water accounted for 59 percent of total irrigation withdrawals in 2000, with ground water supplying the remainder. Ground water is a growing source of agricultural water supplies, increasing from 37 to 41 percent of total withdrawals since 1960. Ground water supplied most of the irrigation water in the eastern 37 States, the area experiencing the most irrigation growth in the past decade. In the Pacific and Mountain regions, surface-water supplies are still the dominant water source (table 2.1.1).

Environmental harm can occur whenever water is withdrawn for agriculture (or any other extractive use). Surface-water withdrawals include either the gravity diversions of rivers and streams or the pumping of water from lakes, rivers, or streams, which can reduce (or totally dry up) streamflow and impair species habitat and wetlands. Ground water is withdrawn with pumps from wells drilled into underground water-bearing strata. When withdrawals exceed natural rates of aquifer recharge, the extraction of ground water can cause land subsidence, reduce total water reserves, and reduce base streamflow, thereby triggering surface-water shortages.

Irrigated Land and Associated Water

In 2002, U.S. irrigated farmland occupied 55.3 million acres, down 1 million acres from 1997 (table 2.1.2). Despite this recent decline, irrigated farmland has increased at an average rate of a half million acres per year over the last three decades, continuing a century-long trend (fig. 2.1.2).

Table 2.1.1
Agricultural water withdrawals, by region and total U.S., 2000

Region	Number of States	Agricultural water withdrawals: Share of total withdrawals	Agricultural water withdrawals: Quantity	Components of agricultural withdrawals: Irrigation	Components of agricultural withdrawals: Livestock and aquaculture	Source of agricultural withdrawals: Ground water	Source of agricultural withdrawals: Surface water
		Percent	*1,000 acre-feet per year*	*Percent*			
Pacific	5	80	45,879	98	2	34	66
Mountain	8	91	64,209	96	4	20	80
Plains	6	49	25,901	97	3	80	20
South	7	30	19,054	95	5	73	27
North-Central & East	24	3	4,409	81	19	72	28
U.S. total[1]	50	41	159,558	96	4	41	59

[1]Excludes water withdrawals in the U.S. Virgin Islands, Puerto Rico, and the District of Columbia.

Source: USDA, ERS, based on Hutson et.al., 2004.

Table 2.1.2

Irrigated land in farms, by region and crop, selected years 1969-2002

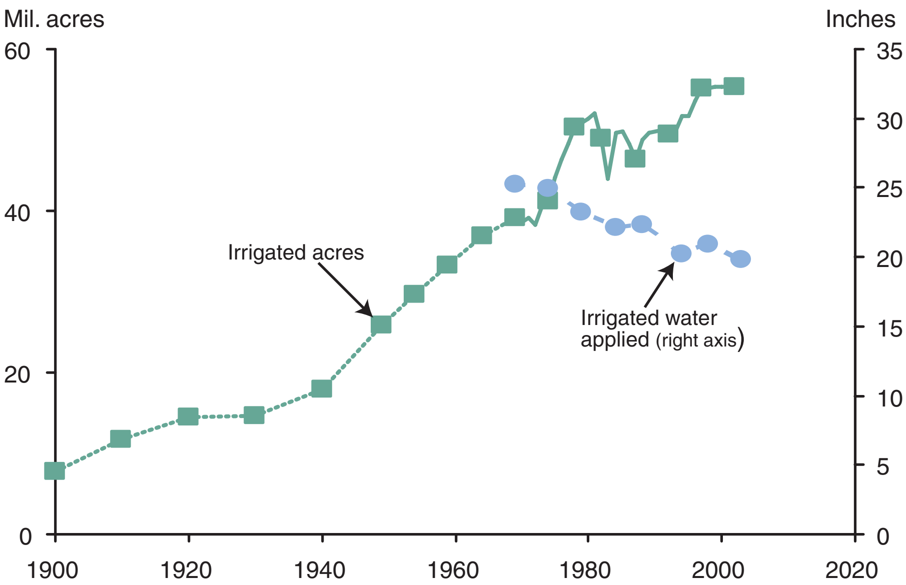
Region or crop	1969[1]		1997[2]		2002[2]	
	1,000 acres	*Percent*	*1,000 acres*	*Percent*	*1,000 acres*	*Percent*
United States[3]	39,100	100	56,289	100	55,311	100
Region						
Eastern regions[4]	4,200	11	12,308	22	13,288	24
Northern Plains	4,600	12	10,312	18	10,907	20
Southern Plains	7,400	19	6,273	11	5,592	10
Mountain	12,800	33	13,603	24	13,011	24
Pacific Coast	10,000	26	13,713	24	12,440	22
Crop						
Corn for grain	3,200	8	10,816	19	9,710	18
Other grains	9,200	24	9,245	16	7,703	14
Soybeans	700	2	4,238	8	5,460	10
Cotton	3,100	8	5,152	9	4,802	9
Alfalfa hay	5,000	13	6,087	11	6,809	12
Vegetables and orchards	3,900	10	6,722	12	6,734	12
Other lands in farms[5]	14,000	36	14,030	25	14,093	25

[1]Census of Agriculture.
[2]Census of Agriculture, adjusted for non-response.
[3]Includes Alaska and Hawaii.
[4]Northeast, Appalachian, Southeast, Lake States, and Corn Belt.
[5]Other uses with more than 500,000 irrigated acres include corn silage, other hay, dry beans, potatoes, sugar beets, nursery crops, cropland pasture, and other pasture.

Source: USDA, Census of Agriculture, selected years.

Figure 2.1.2

Trends in acres irrigated from 1900 to 2002 and water applied from 1969 to 2003



Source: USDA, Census of Agriculture and Farm and Ranch Irrigation Surveys, various years. Variation between Census of Agriculture years from 1969 to 2002 was based on ERS estimates.

Substantial variation within the trend can largely be explained by year-to-year changes in four factors: farm program requirements, crop prices, water supplies in the West, and weather influences on the need for supplementary irrigation in humid areas.

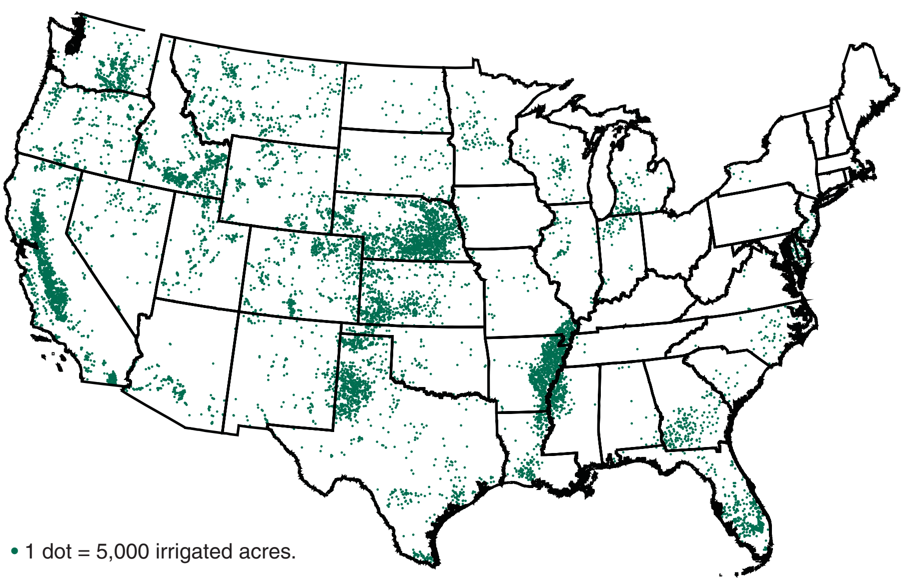
In recent years, national irrigated area has plateaued at about 55 million acres as continuing growth in eastern States has been offset by declines in western irrigation. Since 1988, western irrigated area has been affected by two extended droughts that led to water supply problems, especially in the Southwest. In general, there is an increasing reliance on irrigation in the humid East, and a northward redistribution of irrigation in the West (fig. 2.1.3). In recent decades, large concentrations of irrigation have emerged in humid areas—Florida, Georgia, and especially in the Mississippi Delta, primarily Arkansas and Mississippi.

Averaged over all States and crops, the average depth of water applied has declined by one-fifth (5.4 inches per-acre) since 1969, to annual application levels of less than 20 inches in 2003 (fig. 2.1.2). Agriculture has adopted more water-conserving practices and shifted irrigated production of some commodities to more humid and cooler areas, requiring less supplementary water. Irrigation application can vary from less than 6 inches per acre (sorghum in the North-Central States) to more than 4.5 feet per acre (orchards in the Mountain States). (Water use rates in 2003 were affected by extended drought in the West, especially the Southwest. Surface-water allocations dipped below 50 percent of normal levels in some areas.)

Changes in total water applied to irrigated lands reflect efficiency gains per acre, shifts in crop locations, and changes in acres irrigated. Per-acre declines in application rates (see Chapter 4.6, "Irrigation Water Management") have partially offset the increase in irrigated acreage since 1969. Over 1969-2003, irrigated acreage increased by over 40 percent while total water applied increased by only 11 percent.

Figure 2.1.3

Distribution of irrigated land in farms, 2002



• 1 dot = 5,000 irrigated acres.

Source: USDA/NASS Census of Agriculture, 2002.

Irrigation Water Prices and Costs

Prices paid for irrigation water are of considerable policy interest due to their importance as a cost of production and their impact on water demand. Increasingly, adjusting the water "price" is viewed as a mechanism to improve the economic efficiency of water use. However, water price adjustments to achieve socially desired outcomes can be difficult because prices paid for water are rarely set in a market and generally do not convey signals about water's scarcity. States generally administer water resources and grant (not auction) rights of use to individuals without charge, except for minor administrative fees. As a result, expenditures for irrigation water usually reflect water's access and delivery costs alone—thus, costs to irrigators usually do not reflect the full social cost of water use. (By contrast, those without an existing State-allocated water right—whether an irrigator, municipality, industry, or environmental group—that purchase annual water allocations or permanent water rights from existing users pay prices that more closely reflect the scarcity value of the resource.)

Costs of supplying irrigation water vary widely, reflecting different combinations of water sources, suppliers, distribution systems, and other factors such as field proximity to water, topography, aquifer conditions, and energy source. To generalize, ground water is usually pumped onfarm with higher energy expenses than surface water, which is often supplied from off-farm sources through extensive storage and canal systems. We use data from the Farm and Ranch Irrigation Survey (USDA, 2004b) to examine the cost determinants for ground- and surface-water sources.[2]

Ground water is used on nearly half of U.S. irrigated farms, with the pumped ground water supplying over 32 million acres (table 2.1.3). Energy costs in 2003 ranged from $7 per acre in Maryland to $79 per acre in California, $92 in Arizona, and over $175 per acre in Hawaii. Average costs nationwide were almost $40 per acre, and total expenditures for the sector exceeded $1.2 billion.

Surface-water energy costs reflect pumping and pressurization requirements for conveyance and field application.[3] Over 10.5 million surface-supplied acres incurred these costs in 2003, at an average cost of $26 per acre (table 2.1.3). Costs ranged from $10 per acre in Missouri to $36 in California, $41 in Washington, and $82 in Massachusetts. In general, energy costs are less for pumping surface water than ground water since less vertical lift is required.

Nearly 40 percent of irrigated farms received water from off-farm water supplies, accounting for nearly 14 million irrigated acres. Irrigators paid an average of $42 per acre for water from off-farm suppliers, including about 20 percent of farms reporting water at zero cost (table 2.1.3).

Average costs ranged from $5 per acre in Minnesota to $46 in Washington, $72 in Arizona, and $86 in California. Much of the off-farm water is used in California, with over 30 percent of the Nation's acres served by off-farm sources.

About 120,000 farms, accounting for three-fourths of the irrigated acreage, report incurring maintenance and repair expenses related to irrigation. Costs

[2]Acres irrigated reported in the 2003 Farm and Ranch Irrigation Survey (FRIS) exclude certain types of irrigated farms accounting for about 10 percent of the irrigated land reported in the 2002 Census of Agriculture. FRIS is the sole data source reporting both cost information and acres irrigated by water source.

[3]See the list of pressurized irrigation application technologies in the "Irrigation and Water Use" Briefing Room on the ERS website.

Table 2.1.3
Costs of irrigation water by source and category, 2003

Cost category	Acres incurring the cost		State-level cost range	National average cost	Total national cost
	Million	*Percent*	*Dollars per acre*	*Dollars per acre*	*$ million*
Energy expenses for pumping ground water	32.34	61.5	7- 176	39.50	1,277.54
Energy expenses for lifting or pressurizing surface water	10.56	20.1	10 - 82	26.39	278.72
Water purchased from off-farm sources	13.87	26.4	5 - 86	41.73	578.75
Maintenance/repair expenses	40.01	76.1	4 - 80	12.29	491.77
Total variable costs					2,622.37
Average variable cost (including acres with no cost)				49.87	
Capital investment expenses[1] incurred in 2003	26.67	50.7	16 - 187	42.18	1,125.13

[1]Over $13,000 per farm, distributed based on average farm size to compute per-acre expenses.

Source: USDA, ERS, based on the 2003 Farm and Ranch Irrigation Survey, USDA (2004b).

average over $12 per acre, which increases the cost of water by at least one-third over the cost of water supplies alone (table 2.1.3). In addition, 40 percent of farms reported capital expenditures of over $13,000 per farm for irrigation equipment, facilities, land improvements, and computer technology in 2003.

Policy Issues

Several types of organizations serve as "off-farm suppliers" of water to irrigators, but most are nonprofits that provide dependable water service at low cost. Some such organizations have developed extensive regional water storage and conveyance facilities, while others serve as a local water retailer, transferring water from a wholesaler (such as the Bureau of Reclamation) to water users. Water pricing by these organizations is often based on acreage served rather than water delivered, since administrative costs are lower with acreage-based charges. With this pricing system, producers have little financial incentive to conserve water since charges are assessed independently of how much water allotment is used.

The Bureau of Reclamation (Reclamation), U.S. Department of the Interior, is the primary Federal agency involved in developing and managing water supply projects for irrigation purposes. Reclamation serves as a water "wholesaler" for about 25 percent of the West's irrigated acres—collecting, storing, and conveying water to local entities that, in turn, serve irrigators. From 1902 through 1994, the Reclamation program constructed 133 projects that provide irrigation water, costing $21.8 billion. Irrigation is scheduled to pay less than half of its allocated share of construction costs, with most of the cost subsidized by hydropower revenue (General Accounting Office, 1996). New demands on water for urban growth and environmental restoration in areas with Reclamation projects have focused attention on issues such as the recovery of water-supply subsidies, improved economic efficiency, and increased conservation through water pricing.

Increasing water demands for urban and environmental purposes have prompted discussions on how to more accurately reflect the opportunity costs of water in prices paid by irrigators. Several options exist for States (and in some cases Reclamation) to modify price or quantity allocations to more accurately reflect the scarcity value of water and to improve social benefits.

Voluntary water markets are one prominent strategy to meet new water needs. However, current markets have transactions totaling only 1 to 2 percent of irrigation withdrawals, with volumes concentrated in a few States (Howitt and Hansen, 2005). Markets are most active in areas where there are fewer barriers (defined property rights, institutional flexibility, and developed physical infrastructure), or demand is such that participants are willing to pay significant transaction costs. The most prevalent type of exchange, with nearly 90 percent of the volume, is water leases (especially annual transfers), with permanent transfer of water rights and option markets the remainder.

Irrigated agriculture is likely to remain important, both in terms of the value of agricultural production and demand on land and water resources (National Research Council, 1996). However, changes in the irrigation sector are anticipated in response to increasing water demands for urban and environmental uses, as well as evolving institutions governing farm programs and water allocations. Water diversions for agricultural production will likely continue to decline, with at least some portion shifted to satisfy alternative goals.

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