Department of Agricultural and Resource Economics

The Cardon Endowment for Agricultural and Resource Economics

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ArizonaReview
economic perspectives on Arizona's agriculture and natural resources

The University of Arizona

Harry W. Ayer

An Interview with the *Review's* Founding Editor

Russell Tronstad

In January of 2004, Dr. Harry W. Ayer retired after completing over thirty-four years of service to Arizona's agriculture. Today, he is still actively involved with agriculture through co-editing Euro-CHOICES, a magazine that addresses policy issues related to European and International agri-food and rural resource issues. But now he limits his work to times when his grandchildren have tired of seeing him and his fly rod has been over-exercised. Here we review some highlights of Dr. Ayer's career and then ask him for his perspectives on some key issues facing Arizona's agriculture.

Dr. Ayer's interests and devotion to agriculture started on his parents' crop and livestock operation in Iowa—doing the daily chores and seasonal planting and harvesting field tasks. After Harry completed a bachelor's degree in agricultural business at Iowa State University, he pursued graduate studies in agricultural economics and received an M.S. and Ph.D. from Purdue University. He went to Brazil to collect primary data for his dissertation in the late 1960s—a seminal study that calculated the economic costs and returns to Brazil's major cottonseed research program. This work was funded by the Ford Foundation and received national recognition as runner-up for the Best Journal Article in the *American Journal of Agricultural Economics.* In 1970, Dr. Ayer was hired as an assistant professor with a teaching/research appointment in the Department of Agricultural Economics, College of Agriculture, University of Arizona.

Dr. Ayer was promoted to associate professor with tenure in 1974. In 1977, he went to work for the Natural Resource Economics Division, Economic Research Service/United States Department of Agriculture (ERS/USDA) in Tucson as part of their field staff. While working here, he addressed forward-looking issues, including many that remain of high interest: industrial growth in U.S. border communities and associated air and water problems, impacts of increasing energy scarcity in irrigated agriculture, water pricing in agriculture, solid waste disposal in rural areas, laser leveling, and drip irrigation. He received the USDA Certificate of Merit in 1981 as recognition for the superior quality of work he accomplished in these areas.

Dr. Ayer maintained his ties with the University of Arizona as an adjunct professor and in 1984 he returned as a policy extension specialist. Shortly thereafter he received the Outstanding Extension Program Award from the Western Agricultural Economics Association. His communication skills have been recognized through awards received from Arizona Cooperative Extension and the American Agricultural Economics Association. In particular, he presented economic concepts and policy issues in a way that effectively reached lay audiences, including policy decision makers at both national and regional levels. To take advantage of this talent, the American

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ArizonaReview
economic perspectives on Arizona's agriculture and natural resources

Welcome

to our fifth issue of the *Arizona Review,* published biannually by the Department of Agricultural and Resource Economics (AREC) and the Bartley P. Cardon Endowment for Agricultural and Resource Economics. This issue gives an overview of ongoing research by AREC faculty on water economics and policy. First, emeritus professor and policy specialist Harry Ayer provides insights regarding water and other public policy issues facing Arizona agriculture. Next, Gary Libecap, Robert Glennon, and Alan Ker report on preliminary results from a National Science Foundation-sponsored study of water transfers in twelve western states, focusing on the importance of economic, legal, and political institutions. Bonnie Colby and Katie Pittenger examine the use of dry-year option contracts to carry out voluntary and temporary water transfers, drawing on lessons from other states. Russell Tronstad, Jeff Silvertooth, and Abraham Galadima report on research measuring the value of water for producing end-of-season cotton. Bonnie Colby and Jennifer Pullen then discuss how drought, new water use, and other factors influence the price of water transfers.

Sharon Megdal discusses water management in Arizona, providing an overview on the state's major programs and institutions. Robert Needham and Paul Wilson examine the role of market forces and the Ground Water Management Act on agricultural water use in Central Arizona. Shailaja Deva and George Frisvold present Arizona-specific highlights from USDA's Farm and Ranch Irrigation Survey, the nation's most comprehensive survey of irrigation practices and water use. Dean Lueck provides an update of research, teaching, and outreach activities funded by the Cardon Endowment. Finally, Satheesh Aradhyula and Russell Tronstad update commodity production and price trends in the regular Arizona's Agricultural Situation column.

This issue reflects on the importance of water to Arizona and to AREC faculty. We hope that you will find it useful to further your knowledge about Arizona's most vital natural resource.

—George Frisvold and Russell Tronstad
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The Implications of Legal and Political Institutions on Water Transfers in the West

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Water is arguably the most vital natural resource for continued economic prosperity among the western states. Yet most water rights remain in agriculture and although agriculture remains crucially important to the economic well-being of most western states, it is no longer the economic engine of growth it once was. Hence, there will be continued and escalating pressure for the transfer of water out of low-valued agricultural uses. Transaction costs and weak property rights hinder the transfer of water to higher-valued agricultural, environmental, and urban uses. These transaction costs are manifested through the legal, political, and institutional environments governing water. Our research seeks to determine what legal factors, political institutions, and other factors have facilitated or impeded water transfers so that future policies or laws may efficiently accommodate water transfers among willing participants.

Water Transfers in the West

Water transfers from agricultural to non-agricultural uses between 1987 and 2003 for twleve western states (Arizona, California, Colorado, Idaho, Montana, Nevada, New Mexico, Texas, South Dakota, Utah, Washington, and Wyoming) serve as a basis for our analysis. Figure 1 shows that transfers have generally increased since 1987, but the quantity of water transferred varies across states and time. Figure 2 shows water transfers in selected states.

The twelve states have seen an overall increase in water transfers, but individual states have vastly different patterns in terms of timing and amounts. Our analysis—preliminary at this time—seeks to explain the sources of these differences—in particular, to what extent they are due to state differences in legal definitions of water rights, political institutions, and transaction costs.

The Research

To begin, it was necessary to track the history and changes in water law across the states. We analyzed each of the twelve states to determine what aspects of the law were most important in encouraging or retarding water transfers. Using property rights theory, we developed a list of 71 legal variables that focus on these areas: the definition of a water right; restrictions on a water right holder's use of water;

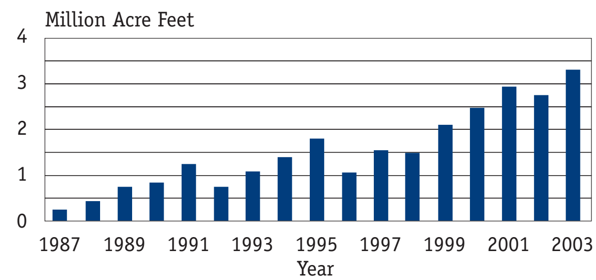
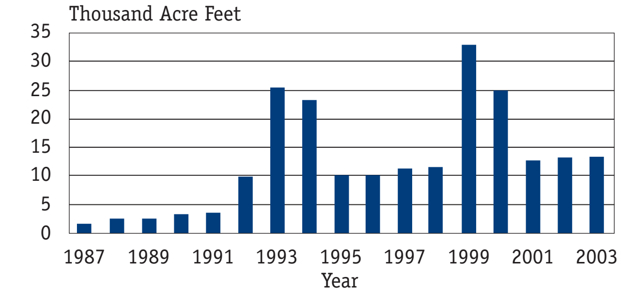
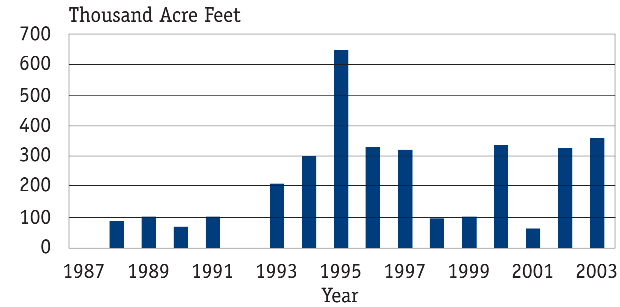


Fig. 1 Water Transfers (Ag to Non-ag): All 12 States

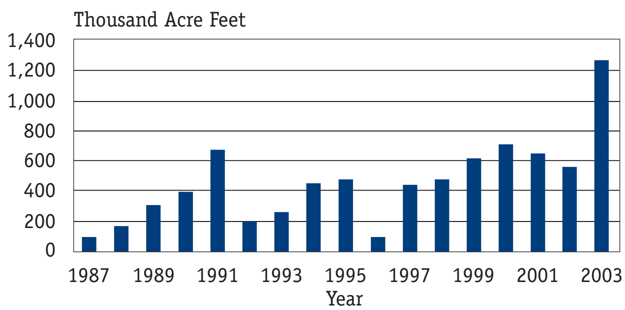
provisions for loss or the limitation of water rights; factors that permit a change in ownership or recognize a right to benefit financially from transfers; conditions placed on the transfer of water rights; conservation measures; regulatory procedures and mechanisms; tribal water rights; and miscellaneous factors. These 71 variables embrace all aspects of state water law from 1980 to 2004 in the west. We then analyzed each state's law across the 71 water rights variables with respect to three types of legal rules: judicial case law, legislative (statutory) law, and administrative regulations. The number of statutes, cases, and administrative rulings varied. For example, in both Montana and Wyoming 150 statutes addressed water rights over the period; there were 80 court cases in



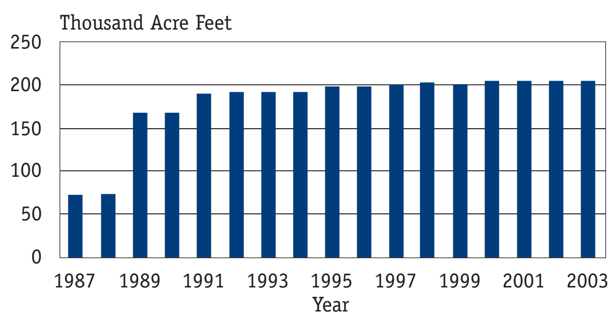
New Mexico



Idaho



California



Arizona

Fig. 2 Water Transfers (Ag to Non-ag)

Montana and 50 relevant administrative rulings, whereas in Wyoming, there were 60 court cases and 100 administrative rulings. Nevada had 200 relevant statutes, 80 cases, and 55 administrative regulations; Utah had 80 statutes, 200 cases, and 50 administrative rulings. As a result, we were left with 213 legal variables to consider in our analysis.

The Findings

Recall, our research was interested in determining what factors facilitate or impede water transfers from agriculture to urban and environmental uses. Our preliminary analysis reveals a number of interesting results:

- the legal environment in a state is crucial to facilitating water transfers;
- well-defined property rights are vital to facilitating water transfers;
- transaction costs impede water transfers;
- environmental issues can impede water transfers;
- demand side factors such as population changes and income are important;
- supply side factors such as competing supply (tribal water), agricultural land, and income are important; and
- political economy variables are insignificant as we suspect that they manifest themselves through the legal environment.

Policy Implications and Future Research

Our empirical results are quite clear: the legal environment can impede or facilitate water transfers through increasing or decreasing transaction costs and through strengthening or weakening water rights. These findings demonstrate that governments can facilitate water transfers if they are willing to adopt policies and laws that minimize transaction costs and strengthen water rights.

The next logical step is to model the development of the law with respect to property rights, transaction costs, the environment, and tribal water rights. We plan to consider how certain sources of the law interact with one another. For example, does case law lead or lag behind administrative law and does legislation regarding water property rights and transfers lead case and administrative law? The nature of the law might also be affected by its institutional origins.

We are also interested in how water transfer law moves across the states. That is, are states more likely to adopt water transfer laws and to clarify property rights if neighboring states have done so? Further, as water becomes more valuable, do individual property rights become more precisely defined as expected, or does the "public trust" doctrine increasingly act to limit private rights? Do federal mandates to protect the environment and endangered species lead to changes in overall water rights and transfer policies in a state? How does the presence of significant tribal water resources affect overall transfers and the development of state law? Do tribal reservations follow water actions on other reservations to promote transfers? While there is much to learn about what facilitates or impedes water transfers, transfers will continue to increase as the economic and demographic landscapes of the western states change. AR

Support for this project was provided by National Science Foudation (NSF) Grant 0317375—Transaction Costs and Institutional Change: An Analysis of Western Water Law Regarding Transfers from Agriculture to Urban and Environmental Uses.

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Voluntary Transfers to Mitigate Drought Costs

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Voluntary and temporary drought-triggered water transfers have been used in many locations throughout the western United States and worldwide to help regions cope with drought. These arrangements generally involve a reduction in crop irrigation in order to make water available for residential, commercial, and industrial water users. The amount paid to irrigators for reducing their water use is negotiated between the parties.

Irrigated cropland is the largest water-using sector in Arizona, based on annual consumptive use. The costs associated with developing new water supplies for improved reliability are generally higher than the cost of temporary transfers of water out of agriculture. Dry-year transfers can be preferable to the outright purchase of senior water rights as a way to ensure water supply protection for cities and industry during drought. Temporary dry-year transfers create less concern about third-party impacts in communities dependent on irrigated agriculture because irrigators maintain their long-term access to water. That is, irrigators' rights to their customary water supplies are preserved and farming in the area continues during normal and wet years.

Factors to Consider in Structuring Dry-Year Transfers

1. The water supply must be adequate for irrigation use in normal years and sufficient for other sectors to use in dry years.
2. The applicable state and federal legal frameworks must be conducive to temporary transfers.
3. Transfers generally focus on annual crop operations that can be temporarily suspended. Perennial crop production, such as vineyards and orchards, are not well suited for temporary fallowing.
4. In order to successfully negotiate price and other terms, buyers and sellers both need realistic information regarding the economic value of water in their sectors and the cost of alternative water supplies.
5. The costs of negotiating and implementing a dry-year transfer, including transaction and transportation costs, must be lower than the buyer's next most costly water supply alternative for dry years.

Where Have Voluntary Dry-Year Transfers Been Implemented?

Oregon. In order to maintain streamflows for migratory fish, the Oregon Water Trust employs split season leasing whereby irrigators use their water in the first half of the season, and then in the second, drier half of the season the Trust leases water from irrigators for instream flow augmentation.

California. In 2001, the California Dry Year Water Purchase Program was established to help secure water supplies for public water agencies and other entities throughout California in the event of drought. Enduring dry conditions in the state have meant the statewide dry-year program has been active since its inception. In a parallel effort, facing drought conditions and cutbacks in its Colorado River supply, the Metropolitan Water District of Southern California has implemented agreements several times in recent years to temporarily transfer water from agricultural districts.

Texas. In anticipation of drought conditions, the Edwards Aquifer Authority in central Texas initiated an Irrigation Suspension Program in 1996. Farmers were paid to forgo crop irrigation during the summer of 1997. Here, dry-year options were used to reduce irrigation water use in order to maintain springflow levels to support federally listed endangered species.

Idaho. In 2001, irrigators in the Snake River watershed were given the opportunity to temporarily fallow land in order to preserve river flows for migratory fish and for hydropower generation. The prices offered were attractive compared to net returns for water use in crop production. Hundreds of farmers signed up to temporarily cease irrigation on 150,000 acres for that crop season. The hydropower benefits helped cover the costs of the program. AR

This work is supported by the University of Arizona, Technology and Research Initiative Fund (TRIF), Water Sustainability Program and by the U.S. Bureau of Reclamation.

Marginal Value of Water for End-of-Season Cotton Production

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Despite rapid urbanization and high production costs, cotton still ranks at the top of cropland acreage in central Arizona. According to *Arizona Agricultural Statistics,* cotton accounted for 39 percent or an average of 159,860 acres from 2001–2003 for Maricopa, Pinal, and Pima counties. If one imputes water applied as represented by the University of Arizona Field Crop Budgets for these counties, cotton accounts for 40 percent of irrigation water applied, a close second to alfalfa and other hay, which account for 43 percent. Given this level of water use, cotton will likely play a key role in Arizona's water management policies for the foreseeable future. In addition, several other factors provide support for continued cotton production in central Arizona. These include the ability to dispose of sewage sludge on a non-food crop, advances in biotechnology and integrated pest management that reduce insecticide use and make it easier for cotton to co-exist near urban housing, groundwater recharge opportunities, tribal water rights settlements, farm program policies, and political support for open space.

Cotton (and other crops) may also provide a water buffer for municipal and industrial uses during periods of drought (see article by Colby and Pittenger on page 5). However, the viability of moving water from cotton to other uses depends greatly on the value of water for producing cotton. This article addresses the value of water for producing cotton after beginning through mid-season crop inputs have already been expended.

Field Data

A field experiment was conducted in 2004 at the University of Arizona's Maricopa Agricultural Center to evaluate how cotton yield, quality, and economic returns depend on a very early through late final irrigation or Irrigation Termination (IT) management. Details of the field trials are available in a 2005 University of Arizona Cotton Report article by Silvertooth, Galadima, and Tronstad.

Temperature largely influences how fast cotton plants develop, so cumulative temperature readings after planting allow one to compare crops across different years and planting dates within a year. Hourly temperature readings were measured using an automated Arizona Meteorological Network (AZMET) station. These readings were then translated to Heat Units Accumulated after Planting (HUAP, 86/55° thresholds) to measure the cumulative time conducive for cotton growth. Station measurements were used to determine five irrigation termination (IT) dates: IT-1, IT-2, IT-3, IT-4, and IT-5. IT treatments ranged from peak bloom (2,000 HUAP) through latter stages in the season sufficient to support a top-crop or second fruiting cycle.

Table 1 Irrigation Application Rates and Dates by Irrigation Termination (IT) Treatment, 2004

	Irrigation Termination Treatment By			
Irrigation Termination Treatment	Calendar Date	Heat Units After Planting	* Total Number of Irrigations	Total Water Applied in Inches
1	22 July	1922	7	42
2	4 August	2386	8	48
3	17 August	2744	9	54
4	27 August	2994	10	60
5	21 September	3616	12	72

*Two initial irrigations were applied to establish crop stand.

All inputs such as fertilizer, water, and pest control were managed on an as-needed basis. Table 1 describes the timing associated with each IT treatment along with the amount of water applied for each IT date.

A key objective of our study was to estimate the value of water "at the margin"—for additional irrigations applied towards the end of the cotton season. This marginal value of water depends on how a longer cotton season impacts both yield and quality attributes. One important lint quality indicator for different irrigation termination dates is micronaire—a measure of fiber fineness and maturity. Fiber fineness affects processing performance and quality of the end textile product. Cotton with micronaire measures that are either too high or too low receive discounted prices. Production conditions and practices that result in higher lint yields can come at the expense of pushing micronaire values higher and the cotton into the price discount range. A higher average micronaire can discount the price received for all cotton harvested, rather than just the additional lint obtained from extending the season. So, the effect of different termination dates on micronaire measures can greatly impact the marginal value of water for end-of-season cotton production.

Results

In general, results showed that higher lint yields were realized with the later IT treatments, but the highest yields came at the expense of high micronaire values. The most favorable economic results were usually achieved with an IT-4 date, which received 12 inches less irrigation water than IT-5. The 12 inches of water saved represents about 20 percent of the total water used under the conventional practice.

The marginal value of water for different irrigation termination dates was evaluated by calculating the additional returns and costs (excluding the cost of water itself) for continuing the cotton crop from one irrigation termination date to the next. Cost assumptions are described in Silvertooth, Galadima, and Tronstad.

We present two scenarios to evaluate the marginal value of irrigation treatments. The first case uses market conditions that correspond with the field trials or November 2004 prices and premium/discount schedules. The second scenario uses the same production responses but with less favorable market conditions for extending the season. It uses the micronaire discount schedule for November 1999 when the discount for lint with micronaire ≥ 5.3 was 22.1¢/lb. This compares with only 4.75¢/lb. for micronaire ≥ 5.3 for 2004. The first scenario is presented in figure 1 and uses a lint price of 60¢/lb. that approximates the floor price cotton producers have under the current farm bill. If our existing farm program structure were to adversely change, lint prices received might not have the same price support either. Thus, a lower base lint price of 45¢/lb. was used to reflect less favorable conditions for extending the season in the second scenario or figure 2.

The marginal (or additional) economic return to an acre foot of water for extending the season from IT-1 to IT-2, IT-2 to IT-3, IT-3 to IT-4, and IT-4 to IT-5 is presented in figures 1 and 2 for five selected varieties. For the first case, water has an economic value that

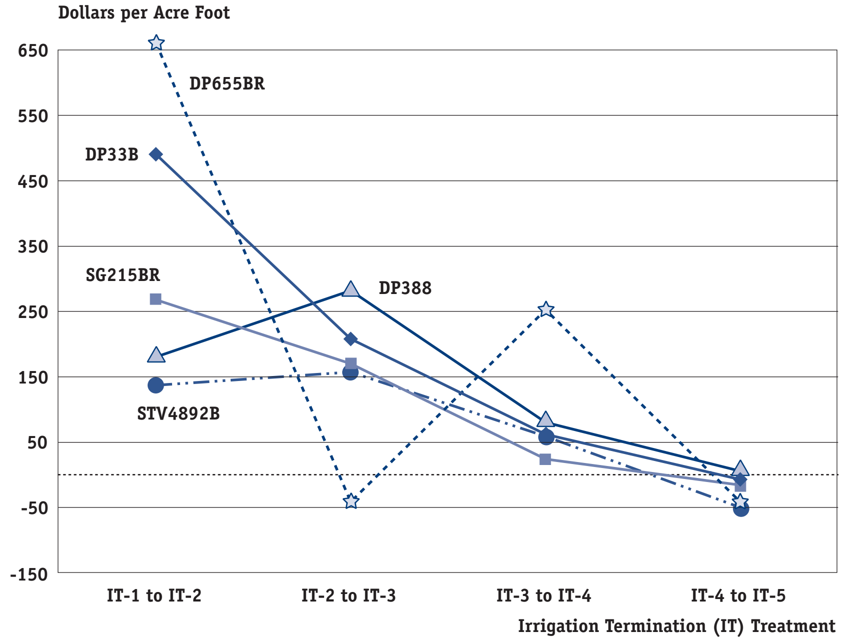

Fig. 1 Marginal Value of Water Using Nov 2004 Market Conditions

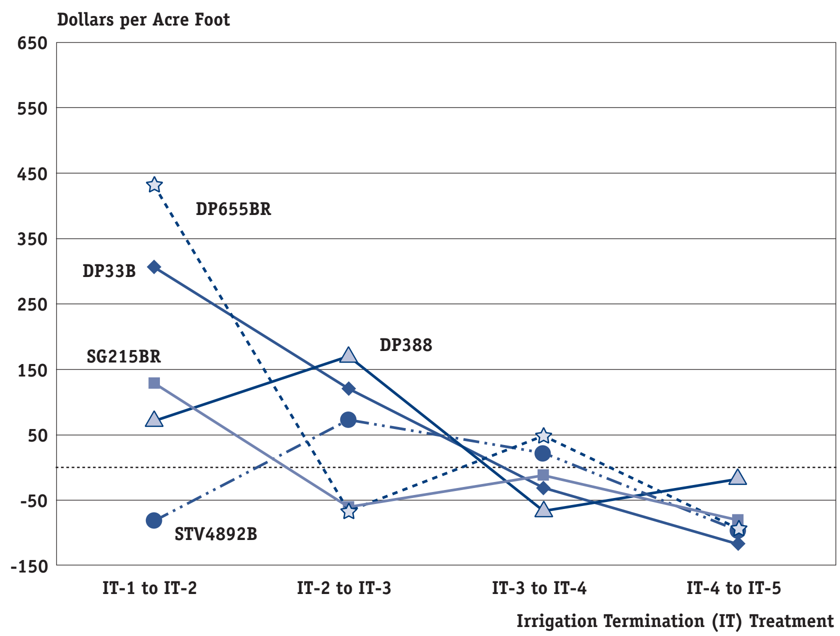

Fig. 2 Marginal Value of Water Using Less Favorable Market Conditions

ranges from $150 to $650 an acre foot for continuing the crop from the first irrigation termination date (IT-1) to the second (IT-2). This wide range is due to some varieties being more short than long season in nature and some being less susceptible to producing high micronaire lint. If drought increased demand for urban uses and caused a squeeze on water availability, the high price of water for urban uses could bid water away from cotton, particularly for shorter season varieties with lower marginal water values. Water at a cost of $100 an acre foot equals only $0.31 per thousand gallons of water. This could be very attractive to urban water districts if quality and transportation issues are not insurmountable. As the season progresses toward the latter irrigation termination dates, variety influences narrow and this produces a smaller range in marginal values for water across varieties. Details regarding all eleven varieties considered are provided in Silvertooth, Galadima, and Tronstad.

Figure 2 shows the marginal value of water under less favorable market conditions for extending the cotton season than conditions in November 2004. On average, the marginal value of water drops by $156.03, $102,00, $87.57, and $66.62 an acre foot using a less favorable lint price of 45¢/lb. and a steeper discount schedule for high micronaire. Here, several varieties have a negative marginal value of water after the second irrigation termination date (IT-2), whereas most varieties have a marginal value of water that exceeds $50 an acre foot up until the fourth irrigation termination date (IT-4) using November 2004 market conditions. Clearly, market conditions greatly impact the profitability associated with continuing the cotton season.

Crop responses to irrigation can vary significantly from variations in weather across years that are not accounted for by HUAP, so caution is warranted. The results presented here are based only on one year. In particular, crops with a substantial early season fruit drop from excessive heat or other factors will likely produce more favorable late season cotton returns than described here. AR

For More Information

Arizona Agricultural Statistics, United Stated Department of Agriculture, National Agricultural Statistics, Agricultural Statistics Data Base, available online at **www.nass.usda.gov/az/**

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Silvertooth, J.C., A. Galadima, and R. Tronstad. "Evaluation of Irrigation Termination Effects on Yield and Fiber Quality of Upland Cotton, 2004." 2005 University of Arizona Cotton Report, available online at **cals.arizona.edu/pubs/**

This work is supported by the University of Arizona, Technology and Research Initiative Fund (TRIF), Water Sustainability Program, and is greatly appreciated. We also gratefully acknowledge the excellent assistance from the personnel at the Maricopa Agricultural Center and the hard work and technical assistance provided by the research assistants from the UA Agronomy program.

Bartley P. Cardon

As most readers already know, Bartley P. Cardon passed away on March 21, 2005 at the age of 91. A special edition of the *Arizona Review* is underway to honor Bart. We have solicited input from a dozen or so close friends and colleagues of Bart's to write a short piece that focuses on personal memories and stories of "The Bart Cardon I Knew." The Bartley P. Cardon Endowed Chair was established in 1997 to honor Bart and recognize his 50+ years of noteworthy contributions to Arizona's agriculture (see the spring 2003 *Arizona Review* issue for highlights of his contributions). The Cardon Endowment for Agricultural and Resource Economics provides resources to help produce and disseminate the *Arizona Review.*

New at AREC

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Voluntary Water Transactions: What Factors Affect Price?

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Voluntary water transfers between willing buyers and willing sellers occur regularly in Arizona and other western states. An ongoing research program headed by Dr. Bonnie Colby examines the factors that affect prices negotiated in these transactions. Below, we report preliminary findings for several different types of transactions.

Some of the factors we examine for possible effects on negotiated prices are the purpose and location of the intended water use, the quantity of water transferred, and water supply conditions (wet versus dry years) at the time of the transaction. The Palmer Hydrological Drought Index (PHDI) shows long-term cumulative dry and wet conditions and is used to examine and compare long-term moisture conditions in a state or region. The PHDI ranges from -8.0 to 8.0, where -8.0 indicates a severe drought and +8.0 represents extreme wet conditions. We include the PHDI in the models below to examine whether negotiated water prices vary systematically across wet and dry periods.

Type II Groundwater Rights

Type II groundwater pumping rights were created within Arizona's Active Management Areas (AMAs), as a part of the 1980 Groundwater Management Act (see article by Needham and Wison on page 13). A Type II right allows the owner to pump a specific quantity of groundwater each year for non-irrigation purposes. Type II rights can be transferred within their own active management area and are commonly leased and sold. (See article by Megdal on page 10 for a map of these AMAs.) Dr. Colby's ongoing research analyzes Type II transactions occurring from 1986 to 2003. We consider how the following variables affect price: number of acre feet purchased, drought index, the year the transaction occurred, new use for the water, and the AMA where the transaction occurred.

Results indicate that the drought index does not significantly affect the Type II pricing model. This is likely because groundwater supplies are not as directly affected by drought conditions as surface flows are, and because Type II rights involve small quantities of water and typically are not relied upon as a backup supply during drought. Our results indicate that Type II water transferred in the Tucson and Pinal AMAs commands a significantly higher price than that transferred in the Phoenix AMA, likely due to the wider variety of potential water sources in the Phoenix AMA (such as the Salt River Project).

Arizona Water Leases

This model examines leases of water over a sixteen-year period, 1987–2003. All types of water leased in Arizona were included in the model (CAP, surface water, groundwater, and reclaimed water). Most leases occurred near Phoenix, but several leases occurred in Tucson and elsewhere in the state. The model examined several independent variables: the number of acre feet leased, year transaction took place, the new use of the water, and the location the transaction occurred.

Results indicate that as drought intensifies—as measured by changes in the PHDI—the price of leasing water increases. The model also examined the effect of the new use of the water. Agricultural and environmental uses were found to be less expensive when compared to water leased for municipal uses, while golf course and landscape leases were more expensive. The location of the transaction did not appear to affect the lease price. AR

Support for this project was provided bythe National Oceanic and Atmospheric Administration (NOAA) through the University of Arizona's Climate Assessment for the Southwest (CLIMAS) Project.

The Importance of Water Storage and Recovery in Arizona

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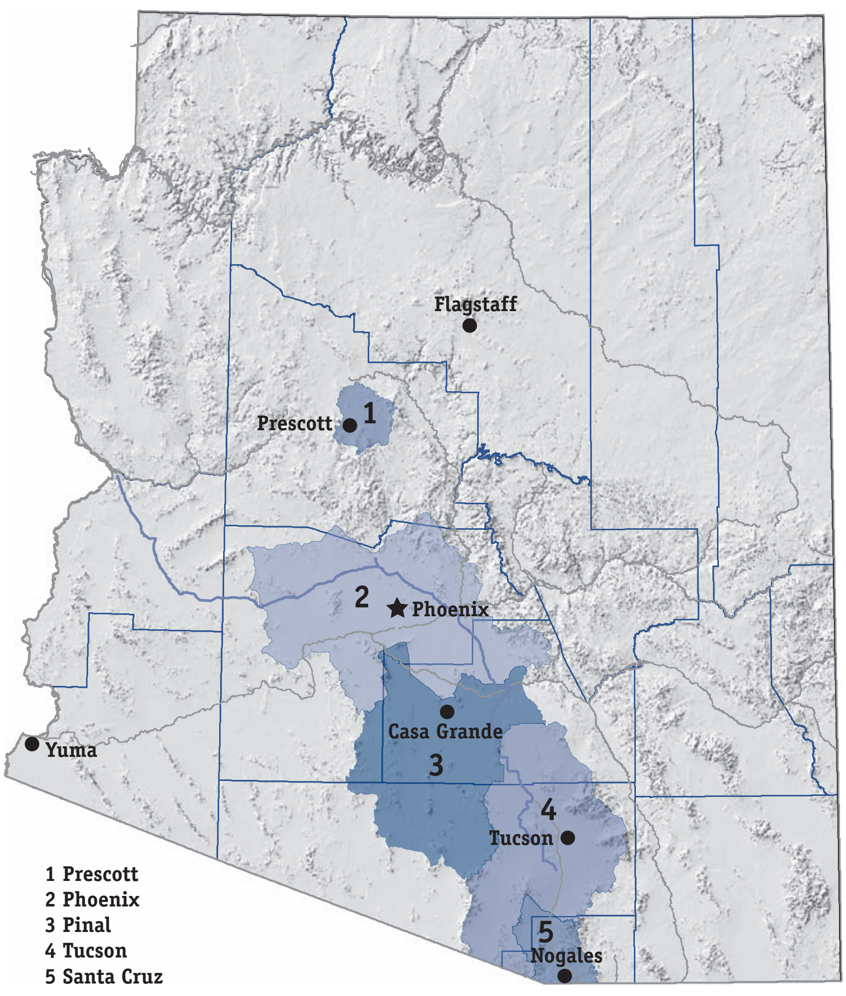
Since adoption of the Groundwater Management Act in 1980, Arizona has been recognized nationally as a leader and innovator in the management of groundwater in the areas of the state known as Active Management Areas (AMAs). AMAs are areas where groundwater overdraft was of such concern that the state regulates its use. The 1980 Groundwater Management Act required that new residential developments have an assured water supply, mandated conservation programs for all water-using sectors, set out regulations on well spacing, and included numerous other regulatory provisions. In the late 1980s, Arizona added to its water management toolbox by introducing a program of water recharge and recovery. The program allows for storage of surface water or effluent through (1) infiltration using basins or streams, (2) well injection, and (3) substitution of renewable water supplies for groundwater use by agricultural entities. Underground storage refers to the first two mechanisms. The third mechanism for storage is called groundwater savings because groundwater is saved when agriculture uses surface water instead of groundwater. The Arizona Department of Water Resources (ADWR) has established a system of permits that governs the construction and operation of all storage facilities as well as the recovery of stored water. Based on report files and the pertinent regulations, credits are accrued for the water stored. These credits allow for the withdrawal of the stored water, often—but not necessarily—at different locations within an AMA and at a future time period. Storage and recovery is authorized for use both inside and outside the state's AMAs, although it is more prevalent at this time inside the AMAs (figure 1).



Source: Arizona Department of Water Resources

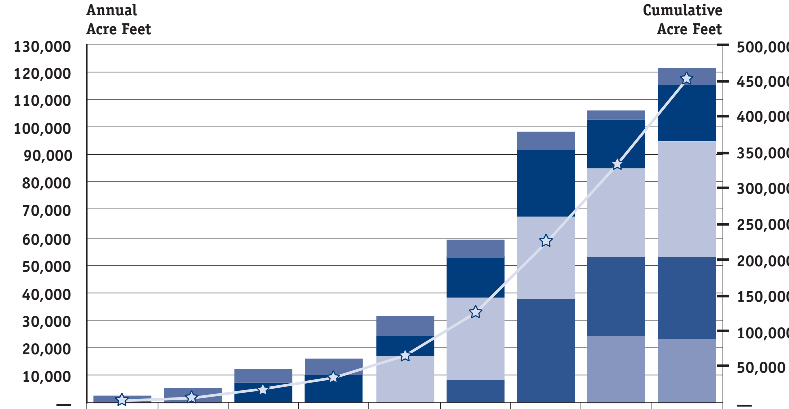
Fig. 1 Active Management Areas

In the 1990s, the Central Arizona Groundwater Replenishment District (CAGRD) and the Arizona Water Banking Authority (AWBA) were created to address additional regional, state, and local water challenges. Both are innovative water management mechanisms and are predicated on Arizona's storage and recovery statutes. The CAGRD is designed to facilitate compliance with the state's Assured and Adequate Water Supply Rules in the three-county area served by the Central Arizona Project (CAP). In Maricopa, Pima, and Pinal counties, the CAGRD is authorized to replenish for its members what is considered excess groundwater use according to the Assured and Adequate Water Supply Rules. Members of the CAGRD include water providers, which are known as CAGRD service area members, and platted developments, called CAGRD member lands. The CAGRD facilitates compliance with the Assured Water Supply Rules' requirement that new growth utilize renewable water supplies rather than mined groundwater. The Board of Directors of the CAP serves as the governing board for the CAGRD.

The primary purposes of the AWBA are to store Colorado River water for future use in times of Colorado River shortages or outage of the CAP canal, to address water management issues, to facilitate Indian water settlements, and to engage in interstate storage on behalf of Nevada and/or California, the other Lower Colorado River basin states. The AWBA is governed by a five-person board that by statute includes the director of the Arizona Department of Water Resources, who serves as its chair, the president of the CAP or his/her designee, and three other members, at least one of whom represents Colorado River cities, one the Phoenix area, and one who is knowledgeable about water management. Since its inception, this last post has been held by a resident of Pima County. Although little known outside of the water community, the AWBA has been instrumental in showing that Arizona can fully utilize its 2.8 million acre foot Colorado River entitlement. Since the 1980s, about 4 million acre feet of water have been stored in Arizona, with approximately half of that volume stored by the AWBA.

Arizona's storage and recovery programs are integral to efforts to develop sustainable water supplies for communities throughout Arizona. They enable surface water to be utilized by agriculture at a cost lower than would otherwise be available and they provide alternatives to treatment and direct delivery of surface water to municipal customers. In addition, they facilitate the storage of water for future use. This storage is particularly important to users dependent on low-priority Colorado River water allocations, such as CAP customers and certain cities along the Colorado River. Millions of dollars have been invested in water storage projects and millions more are slated for investment.

Figure 2 shows annual as well as cumulative storage at five underground storage projects constructed by CAP using funds collected in Pima and Maricopa counties between 1991 and 1995. A special State Demonstration Recharge Project tax (4 cents per $100 assessed valuation) was levied by the CAP board, pursuant to legislative authorization, for that five-year period. In addition



	1996	1997	1998	1999	2000	2001	2002	2003	2004
AVRA	2,810	5,554	4,939	5,782	6,976	6,310	6,805	3,539	6,084
PMRRP	—	—	7,382	10,480	7,408	14,701	24,708	17,959	20,812
LSCRP	—	—	—	—	16,670	29,894	29,989	31,909	41,720
AFRP	—	—	—	—	—	8,462	37,399	28,736	30,050
HMRP	—	—	—	—	—	—	—	23,852	23,058
☆ Cumulative	2,810	8,364	20,686	36,947	68,001	127,367	226,268	332,263	453,987

AVRA: Avra Valley Recharge Project, Marana, Pima County
PMRRP: Pima Mine Road Recharge Project, near Sahuarita, Pima County
LSCRP: Lower Santa Cruz Replenishment Project, Marana, Pima County
AFRP: Agua Fria Recharge Project, West Valley, Maricopa County
HMRP: Hieroglyphics Mountains Recharge Project, East Valley, Maricopa County

Note: Only CAP-operated recharge projexts listed.
Source: Central Arizona Project

Fig. 2 1996–2004 Cumulative Recharge Project Deliveries

to funding the construction of these recharge projects, Maricopa County tax revenues were used to fund water storage at the Granite Reef Underground Storage Project (below, next page), which was built and operated by the Salt River Project (SRP). This temporary tax for state demonstration recharge projects was instrumental in the development of underground storage facilities. Among the entities storing water at these facilities are CAGRD, the AWBA, and water utilities.

The importance of Arizona's storage and recovery programs, as well as some of the challenges, was recognized during deliberations of Governor Hull's Water Management Commission and, more recently, at the Fall 2004 Arizona Town Hall. The Final Report of the Governor's Water Management Commission, issued December 2001, acknowledged the importance of the recharge and recovery programs. However, the recommendations noted unresolved issues related to the location of replenishment or recharge, the recharge permitting process, and the need for recovery of water stored by the AWBA. It was expected that a thorough examination of recovery would be undertaken following the December 2001 conclusion of the Commission's deliberations. This comprehensive and collaborative examination of recovery is still pending.

Arizona's Water Future: Challenges and Opportunities (the background report for the Fall 2004 Arizona

Bay of Water Recovery Wells Source: Tucson Water

Town Hall) provided information on recharge and recovery, the CAGRD, and the AWBA. Deliberations of the 175 business and community leaders from across Arizona concluded: "To avoid crisis management, the ADWR must play a bigger role in water management and be proactive. It should immediately implement a comprehensive water storage and recovery planning process. It must have the necessary funds, staffing and resources to accomplish its goals." The need for more public investment in storage facilities and "the means to deposit and recover recharged water" was indicated. The Report of the Town Hall stated: "Proper funding is necessary for physical infrastructure. The cost of any new infrastructure should be evaluated in light of its anticipated benefits."

Recharge is not only important to the Active Management Areas, but also in rural areas in the state where watershed groups are working on local and regional water management issues. In a recently released report, ADWR Director Herb Guenther concluded that the Upper San Pedro Basin of Arizona should not be a declared an AMA. Mr. Guenther noted, however, that "…implementation of recharge projects [has] positive benefits in reducing groundwater overdraft… Such local efforts should be continued throughout the basin."

In the March/April 2005 issue of *Southwest Hydrology,* which focuses on drought on the Colorado River, the importance of the interstate banking component of the AWBA's authorities is cited as contributing to the "integrity of the [Colorado River] allocation system

Agua Fria Recharge Project Source: Central Arizona Project

established under the Boulder Canyon Project Act of 1928." The same issue reports on the historic water storage agreement signed in late 2004 by the Southern Nevada Water Authority and the AWBA. The program for recovery of the stored water, including its cost, has yet to be specified.

Nationally, the importance of water institutions, such as the storage and recovery programs, CAGRD and AWBA, was recognized in *Envisioning the Agenda for Water Resources Research in the Twenty-First Century*. The report cites "[t]he importance of legal regimes that promote groundwater management and conjunctive use of surface water and groundwater" and conducting comparative studies of water laws and institutions. The need for additional research on water institutions was further emphasized in *Confronting the Nation's Water Problems: The Role of Research*. The recent report, *Science and Technology to Support Fresh Water Availability in the United States,* discusses the importance of developing additional storage capacity and "[i]mproved understanding of the processes that can affect the utility of storing water in aquifers by artificial recharge, including aquifer storage and recovery."

Practitioners and researchers representing many disciplines, including economics, are involved in investigations related to water storage and recovery. It is important that we understand the implications, including those on water quality, of long-term storage of water or storage on behalf of our neighboring states. And, for obvious reasons, it is important that we know at what cost the stored water will be available when we need to recover it. AR

Granite Reef Underground Storage Project Source: Salt River Project

***Sharon B. Megdal's** work focuses on Arizona water resources policy and management. Active areas of research include the role of the private sector in water delivery and long term water storage, regional approaches to water management, and how the desert's landscape has been affected by water management. She writes a public policy column for the* Arizona Water Resource, *the bi-monthly Water Resources Research Center newsletter, and regularly makes presentations on water matters to diverse audiences.*

Water Conservation Policy in Arizona Agriculture:

Assessing the Groundwater Management Act of 1980

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For twenty-five years, the Groundwater Management Act of 1980 (GMA) has been regarded as the dominant water management policy tool for central Arizona agriculture. The GMA emerged from a period of growing tension in central Arizona throughout the 1960s and 1970s over the role of groundwater in meeting the expected demands of a growing urban population and a prosperous agricultural sector. A series of three major events led political leaders to the negotiating table to fashion legislation promoting the conservation and management of groundwater. First, a series of legal decisions (Jarvis v. State Land Department, 1969, 1970, 1976) eventually established the right and quantified the amount of water cities could extract from off-site municipal locations and transport to municipal consumers. Secondly, the court determined in the Farmers Investment Company case (FICO v. Bettwy, 1976) that mines could no longer withdraw groundwater from neighboring lands and transport the water away from those lands for use in the mining operations because of the damage done to neighboring wells. The FICO court ruling threatened the ability of mines and cities to meet their long-term water needs without buying large acreages of farm land. Finally, within this uncertain legal environment, the federal government threatened to discontinue funding for the Central Arizona Project (CAP), a 336-mile aqueduct importing Colorado River water into central Arizona, unless the state passed a comprehensive groundwater management code.

The Groundwater Study Commission, created by the State legislature in 1977, was charged with studying the possibility of a comprehensive reform of existing groundwater law. Specifically, the Commission was given the responsibility to (1) clarify conflicting groundwater rights claims, including transportation rights, (2) design a management plan for critical overdraft areas, (3) institute a program to encourage efficient water use, (4) manage water for future population growth, and (5) protect the environment. After two years of intense negotiation between mines, cities, and agriculture, and discussions with the Arizona legislature, the Groundwater Management Act (GMA) of 1980 was signed into law on June 11, 1980. The GMA passed the special session of the legislature in one hour and fifteen minutes with minimum debate, the shortest special session in state history. The Arizona Department of Water Resources (ADWR) was established in the GMA to implement and enforce the new water code. The GMA has won acclaim and awards over the years for its approach to groundwater management.

The GMA initially established four Active Management Areas (AMAs) with three of the four situated in important agricultural/urban areas where a long history of groundwater overdraft (nearly two million acre feet per year) threatened the long-term viability of farming and urban expansion. The legislative goal in the Phoenix and Tucson AMAs was safe yield, or zero overdraft, by 2025. In the Pinal AMA, a relatively more agriculturally dependent region, the goal was to preserve farming as long as possible without jeopardizing municipal water supplies. Water conservation practices, in all economic sectors, would be mandated via increasingly restrictive policies on water use.

In the case of agriculture, the GMA regulated water use by (1) not allowing the development of new agricultural land, and by (2) a series of management plans that intended to gradually reduce the quantity of water available to the grower in a given year. Annual water allotments represented the amount of water a grower could use from wells, surface supplies (unless 100 percent CAP water was utilized), or both. ADWR requires the measurement and reporting of actual water use with flow meters on all wells and irrigation district-managed turnouts in all AMAs. Allotments were calculated for all farm units on the basis of water use records and the crops grown in the five years preceding the GMA (1975–1979). If a grower used less water than his allotment in a given year, that grower could bank the difference in a flexibility account (known as flex credits). In a year when a grower had greater demand for water than his annual allotment, because of increased crop acreage or hotter weather or the choice to grow more water-intensive crops, the grower could use his accumulated flex account credits or, starting in 1991, buy flex credits from other growers in order to maintain the economic productivity of the farm.

Impact Assessment Design

Program evaluation is a social science tool that systematically analyzes the effectiveness of program performance relative to program goals. Our fundamental question is "Has the GMA promoted water conservation in agriculture?" Our mixed-method evaluation of the agricultural water conservation component of the GMA combines qualitative and quantitative causal analysis to assess program outcomes.

In our qualitative analysis we conducted in-depth, open-ended interviews with three groups: (1) current or former ADWR staff, (2) irrigation district managers, and (3) other recognized water experts, analysts, and growers. We explored with these groups alternative explanations for outcomes in the agricultural water conservation programs. We chose this triangulation approach (i.e., using three sources of information or analytical methods) because it inherently contains checks and balances for the analysis—giving the evaluation greater strength and rigor than single method evaluations.

For the quantitative analysis, ADWR water use data and irrigation district water prices were combined with other economic variables to estimate water demand by each irrigation district over the study period, 1984–2002. In this second form of triangulation, results from the in-depth interviews were cross-checked with the data from ADWR and our statistical analysis.

Analysis

We interviewed ten irrigation district managers, ten current or former staff members of ADWR, and twelve water experts, analysts, and growers, thirty-two interviews in all. We also gathered water purchased, water pumped, price, weather, and acreage data for eleven irrigation districts in the three AMAs from 1984–2002. These eleven districts represent 69 percent of the irrigated acreage in these AMAs.

This data allowed us to conduct statistical analysis of water demand across time in eleven irrigation districts. With structural, institutional, and operational knowledge of these districts, we explain, at least partially, the variation in water demand across districts. Secondly, the approach allows us to test the relative impact of the First, Second, and Third Management Plans of the GMA on agricultural water demand, controlling for other factors such as economic conditions and weather.

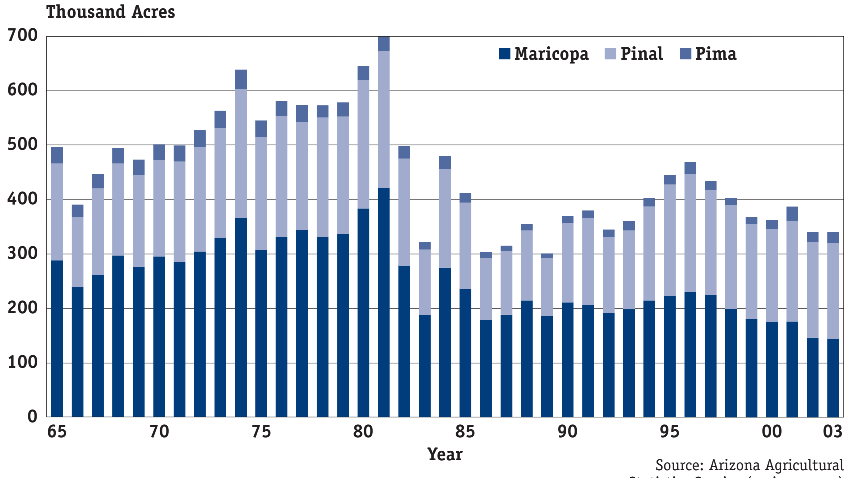
Results

It is a widely shared belief among water experts in the state that individual farms adopted water conservation technologies in the late 1970s and throughout the 1980s. The passage of the GMA created a perception of an impending water constraint. The fear that this legislation could hurt agricultural operations in the future induced some growers to line their ditches and laser level their fields. Simultaneously, the impending arrival of CAP water in central Arizona encouraged some farmers to level fields, create level basins in their fields, and construct high volume turnouts. Experts agree that individual farms adopted water conservation improvements during the study period but that most of these decisions had very little to do with the conservation requirements in the First and Second Management Plans. The only legislated policy that "conserved" water for the future was the requirement that irrigated acreage could not be expanded in the AMAs beyond the acreage in the 1975–1979 period.

Our quantitative, econometric results are consistent with these overall findings. Water prices, crop prices, weather, and acreage cropped explain nearly all the variation in water purchased and pumped over the study period. Conservation provisions in the First, Second, and Third Management Plans had no noticeable impact on the quantity of water utilized by growers.

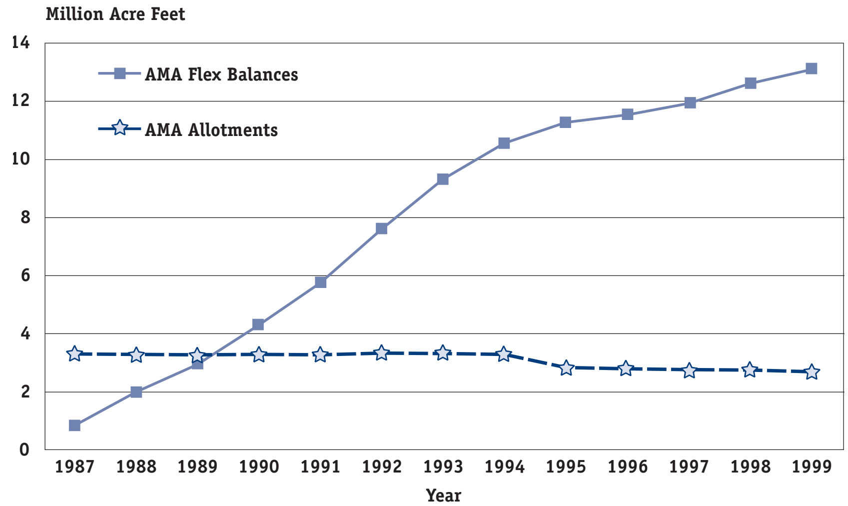
Why did the GMA have little impact on water conservation decisions? First, the Act and the implemented management plans did not establish an effective water constraint for most farms. Rather, the legislation established a "constraint" that was infrequently binding on the decision making of most growers. The GMA established 1975–1979 as the period used to determine water duty acres, the highest number of acres irrigated during this period and authorized to receive a water allocation. This period represents the peak of irrigated acreage in central Arizona over the last forty years (figure 1). To compound matters, for the first management plan ADWR calculated a generous water duty based on average crop needs during 1975–1979. As a result, most growers, but not all, felt no binding water constraint on their irrigation water use.

A second factor in creating an ineffective water constraint was the design and implementation of the flex account program in 1986–1987. Growers had the right to "bank" portions of their water allotments that were not used in a given year. Farmers could accumulate these credits over the years and withdraw them when they increased their cropped acreage (within GMA



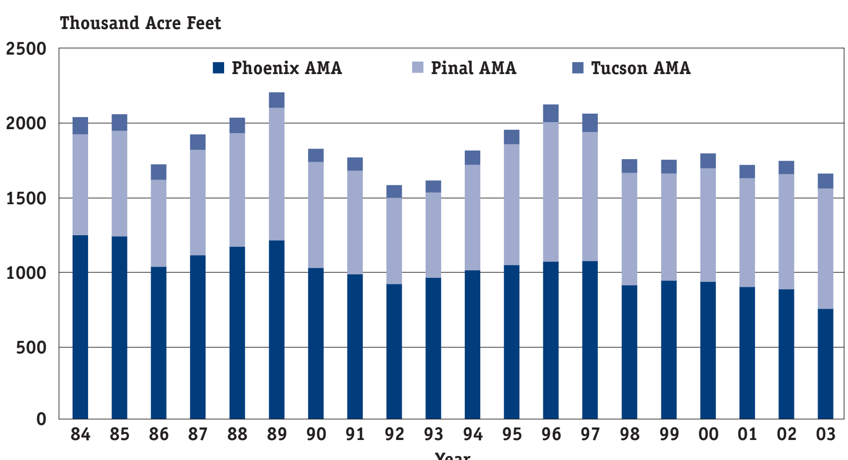
Source: Arizona Agricultural Statistics Service (various years)

Fig. 1 Irrigated Acres of Principal Field Crops



Source: Arizona Department of Water Resources

Fig. 2 Flex Credits and Allotments for Phoenix, Pinal, and Tucson AMAs



Source: Arizona Department of Water Resources

Fig. 3 Agricultural Water Use

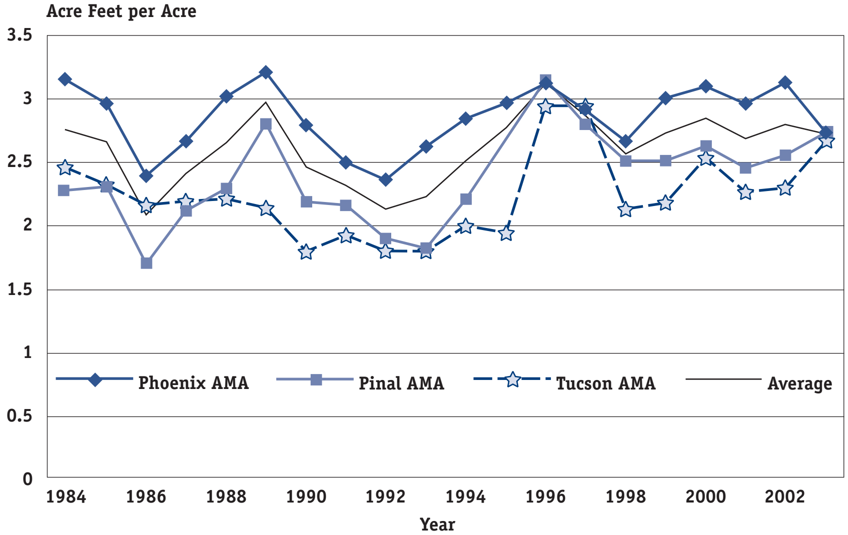
limits), experienced a hot summer, grew more water-intensive crops, or farmed more intensively. They also could sell a limited number of credits to other farmers within their district or groundwater sub-basin after the GMA amendments of the 1990s.

Accumulated flex credit accounts have grown to tens of thousands of acre feet of water for individual farms for several reasons. First, during the 1980s the agricultural economy went through a period of low commodity prices and high interest rates. Low profitability and credit constraints reduced acreage planted and water use, but increased flex credits. Secondly, until 1996, federal commodity programs required growers to set aside a portion of their land to receive commodity program payments. These set-aside acres earned flex credits. At present, the average flex credit account in the three AMAs represents six years of irrigation water for the "average" grower, (figure 2). In summary, generous water allotments combined with generous flex credit provisions created a decision environment in agriculture where water availability was not a binding constraint for most growers.

Growers respond to market signals when evaluating the profitable adoption of water-conserving irrigation technologies and practices. Declining crop prices and low, stable water prices over the last half of the study period served as disincentives to the adoption of costly technologies or to a significant change in water management practices. Aggregate water use in the agricultural sector has declined slightly due to urbanization in some of the irrigation districts in the Phoenix AMA (figure 3). However, the trend in per acre water use in the agricultural sector has remained relatively constant over the life of the GMA (figure 4). As noted earlier, fluctuations in water use over this period are explained largely by changing crop prices, input costs, weather, and macroeconomic conditions (e.g., interest rates, urbanization). A final note: it is important to realize that groundwater has been conserved in the three AMAs over the later half of the study period because low-cost CAP water has been available to the agricultural sector.

So What?

The GMA has raised the visibility of water issues in the state over the last twenty-five years. Required recordkeeping, reports, planning, and negotiation sensitized the agricultural sector to its important role in the management of water resources in the state. The GMA currently serves as a valuable framework for policy analysis and discussions. However, the agricultural water conservation provisions of the First, Second, and Third Management Plans of the GMA by themselves



Source: Arizona Department of Water Resources

Fig. 4 Per Acre Water Use in Agriculture

did not create significant incentives for on-farm water conservation practices and technologies. While many growers have adopted water conservation practices and technologies over the past twenty-five years, factors other than the management plans have been largely responsible. The GMA changed the political environment, but the management plan provisions did little to change the economic incentives or water management decisions of most agricultural business managers. Many water experts interviewed for this study concluded that education (e.g., irrigation management) and economic incentives (e.g., tax credits, cost shares, prices) may be lower cost and more effective tools for achieving desired water conservation goals in the agricultural sector. AR

Final results from this study will be available in September 2005. Please contact Paul Wilson (pwilson@ag.arizona.edu) for a copy of the final results and for any other questions concerning this research project. *This work is supported by the University of Arizona, Technology and Research Initiative Fund (TRIF), Water Sustainability Program.*

Some Highlights from the 2003 Farm and Ranch Irrigation Survey

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Results of the 2003 Farm and Ranch Irrigation Survey (FRIS) were first made public in November 2004. The 2003 FRIS is the sixth survey devoted entirely to the collection of on-farm irrigation data for the United States. The 2003 FRIS—a follow-on survey to the 2002 Census of Agriculture—provides an extensive and comprehensive picture of irrigation practices and water use at the national and state level. Here we present just a sample of the types of information for Arizona available online from the survey.

Background

The United States Constitution requires that a census of population be conducted every 10 years. In 1840, the census began collecting more detailed information about agriculture. Irrigation data have been collected from farms and ranches in the census of agriculture since 1890. The 2003 survey is the most recent, but surveys from 1998 and 1994 are also available online.

Changes in Irrigated Acres

Acres receiving irrigation applications in Arizona fell over 4 percent between the 1998 and 2003 surveys. Figure 1 shows changes in irrigated acres for selected crops in the state. Grains, cotton, and orchards and nuts experienced the greatest declines in acreage, while vegetables, alfalfa, other hay, and corn silage had gains in acreage. The 1996 farm bill increased planting flexibility, allowing growers to substitute between field crops without being penalized with lower commodity program payments. The growth in Arizona's dairy industry has contributed to the growth in alfalfa, hay, and corn silage production in the state. Between 1998 and 2003, Arizona dairy herds increased by 18 percent and milk production increased 35 percent.

Applications and Application Rates

In 2003, 836,587 acres in Arizona were irrigated with applications of 3.75 million acre feet of water. An acre foot is the amount of water needed to cover an acre, one foot deep in water. One acre foot equals 325,851 gallons and 1 million gallons equals 3.07 acre feet. Applications are respondents' estimates of water applied to crops and do not measure total water withdrawn from surface and groundwater sources. By way of comparison, the U.S. Geological Survey estimates that 6 million acre feet were withdrawn for irrigation in 2000. Applications also do not measure conveyance losses, return flows of irrigation water back to aquifers and water bodies, or consumptive use—the amount of withdrawn water lost to evaporation, plant transpiration, and incorporated into products or crops.

That said, approximately 4.5 acre feet were applied per acre on Arizona's irrigated crops and pastures in 2003. Application rates (acre feet per acre or AF/acre) vary substantially by crop and year. Figure 2 compares application rates for selected Arizona crops for 1998 and 2003, the two most recent FRIS years. Rates vary from 2.5 AF/acre for barley in 1998 to 5.8 AF/acre for alfalfa in 2003.

Application rates also vary greatly by irrigation technology. Sprinkler and drip systems can apply water more efficiently than gravity systems. Gravity flow systems are the dominant irrigation systems in the state. With gravity systems, water is conveyed to the field using open ditches or pipe, and released along the upper end of the field through siphon tubes, ditch gates, or pipe valves. About 90 percent of Arizona's acreage was irrigated with gravity systems, while farms relying solely on gravity systems accounted for 68 percent of irrigated acreage. Farms relying solely on sprinkler irrigation applied an average of 3.4 AF/acre but accounted for only 8 percent of irrigated acres in the state. Farms relying solely on drip irrigation also applied 3.4 AF/acre on average, but accounted for less than 2 percent of irrigated acreage.

Water Use Varies by Farm

In 2003, 699 farms—25 percent of farms in the state—applied 500 or more acre feet of water each (figure 3). These farms applied 97 percent of Arizona's irrigation water. The remaining 75 percent of farms (2,078 in all) applying less than 500 acre feet accounted for 3 percent of all irrigation applications. Farms applying 2,000 acre feet or more accounted for 16 percent of farms, but 89 percent of irrigation water applied. Because farms vary so much in their contribution to overall water use, one must exercise care in measuring farm-level irrigation behavior. To get a clear picture of

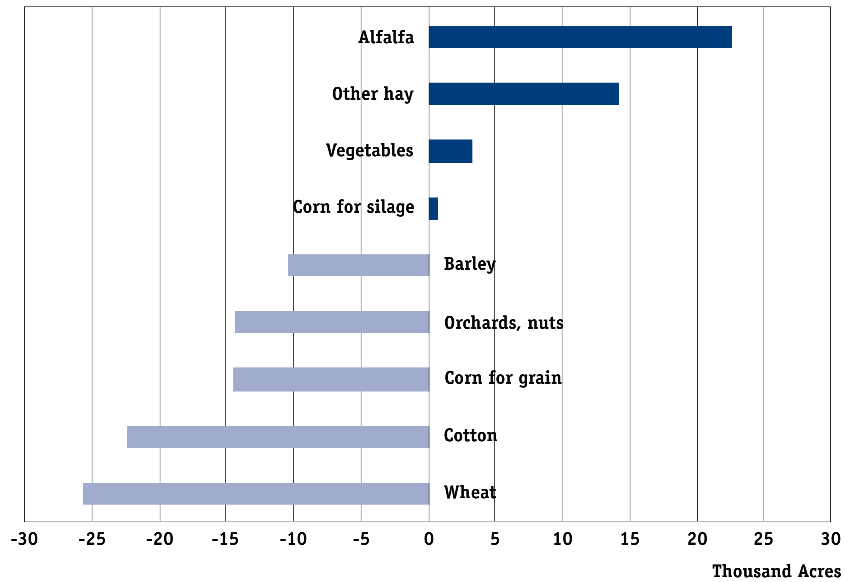


Fig. 1 Change in Harvested Acres for Selected Arizona Crops, 1998–2003

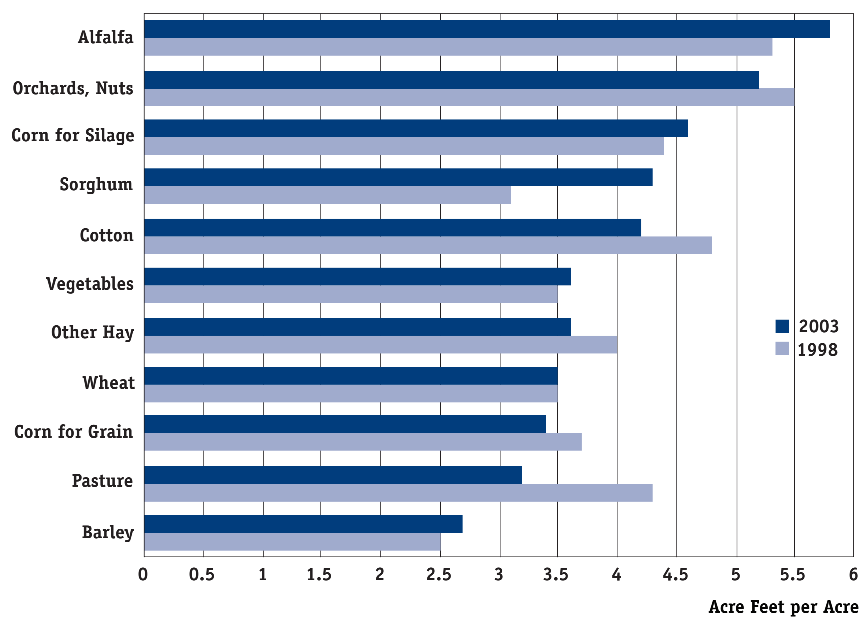


Fig. 2 Water Application Rates for Selected Arizona Crops, 1998 and 2003 (Acre Feet per Acre)

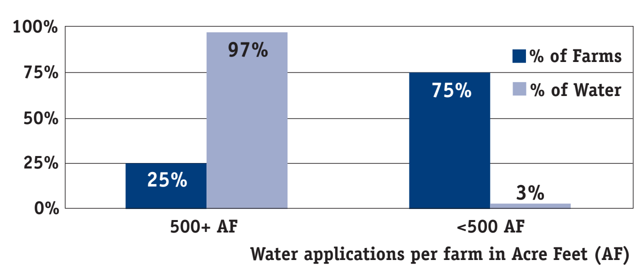


Fig. 3 One-Quarter of Farms Apply 97% of Arizona's Irrigation Water

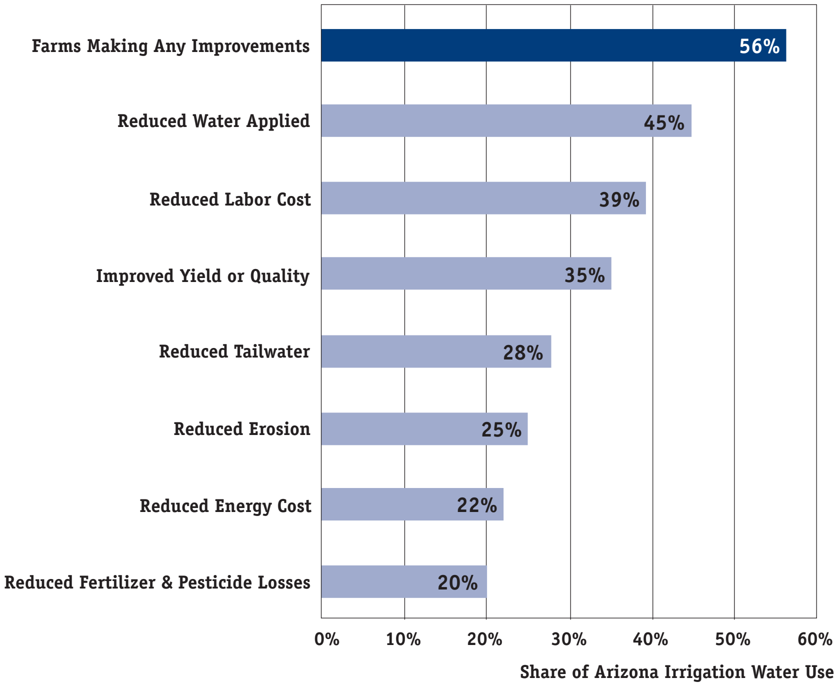


Fig. 4 Effects of Conservation Improvements in Previous Five Years (by Share of Arizona Irrigation Water Use)

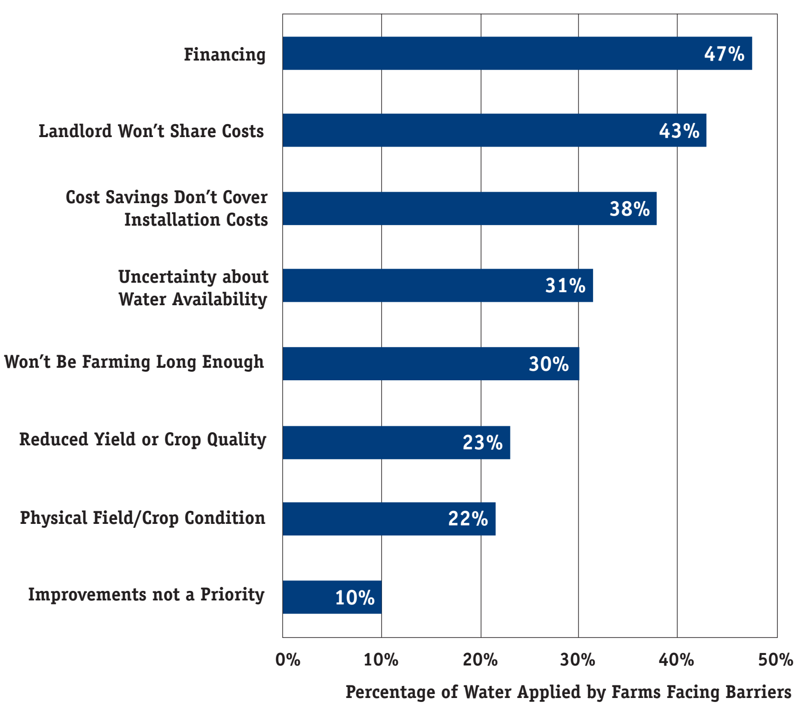


Fig. 5 Barriers to Making Improvements to Lower Energy Costs or Conserve Water (by Percentage of Water Applied by Farms Facing Barriers)

overall water management patterns, it is important to capture the importance of those farmers accounting for most of the irrigation. In the figures we report next, we weight responses by the amount of water applied or the number of acres irrigated.

Irrigation Investments

In 2003, Arizona farms invested over $21 million in irrigation equipment, facilities, land improvement, and computer technology. Of this, $11.2 million went to replace old equipment, $6.7 went to water conservation investments, and $3.2 million went to new expansions.

The survey asks farmers and ranchers if they have implemented any energy or water conservation improvements over the last five years. Figure 4 summarizes responses weighted by the amount of irrigation water farms applied. Respondents that accounted for 56 percent of water applied made conservation improvements in the last five years. Figure 4 also shows what respondents thought the effects of those improvements were. Respondents could choose more than one project and effect. Respondents accounting for 45 percent of water applied made improvements that reduced water applications. Other important effects were reduced labor costs (39%), energy costs (22%) and improved crop yield or quality (35%). The average cost of water purchased from off-farm sources was about $72 per acre (or $16/AF). Irrigation labor costs ran about $47 per acre, while energy pumping costs averaged $25/acre for surface water and $92/acre for groundwater. Investments were also made that improve environmental quality. These include investments to reduce soil erosion (25%), fertilizer and pesticide losses (20%) and tailwater, the runoff from the lower end of an irrigated field (28%).

Barriers to Conservation

Farmers were also asked about barriers to making improvements in conserving energy or water. In all, respondents accounting for 1.6 million acre feet applied—44 percent of the state total—reported facing some barrier to conservation improvements. This is up from 41 percent in the 1998 survey.

Figure 5 shows a breakdown by barrier for those farmers facing constraints. Again, percentages are weighted by water applied. Of farms facing barriers to conservation improvements, the most common barriers are financial. Farms accounting for 47 percent of water applied could not finance improvements. Other economic reasons given were that landlords would not share the cost of improvements (43%) and that reduced costs from conservation would not outweigh the initial installation costs (38%). Few farmers thought investigating improvements were not a priority (10%), while others cited physical field constraints (22%) and concern about reduced crop yield or quality (23%).

Because irrigation investments require large up-front costs, growers must anticipate farming long enough to re-coup these initial outlays. Other barriers to adoption were uncertainty about future water availability (31%) and operators' belief that they will not be farming long enough to justify improvements (30%). Of 2,777 farms, 63 responded that they will not be farming long enough to justify improvements. These 63 operations applied 486,647 acre feet of water in 2003.

Information to Reduce Costs and Conserve Water

The FRIS survey also asked farmers what sources of information they relied upon to reduce irrigation costs or conserve water. Figure 6 provides a breakdown of responses weighted by irrigated acres. Farmers could rely on more than one source. The two most common sources were neighboring farmers (51%) and extension agents and university specialists (48%). Next in importance was staff of USDA's Natural Resources Conservation Service (NRCS) and other federal, state, or local agencies (33%). To a lesser extent, farmers relied on independent consultants, equipment dealers, and irrigation districts. Farmers accounting for 8 percent of irrigated acres relied on electronic (Internet-based) services.

The 2003 FRIS also presents more detailed data about irrigated acreage and application rates by crop, irrigation technology and management practice choice, well depth, and groundwater pumping (and other) costs. AR

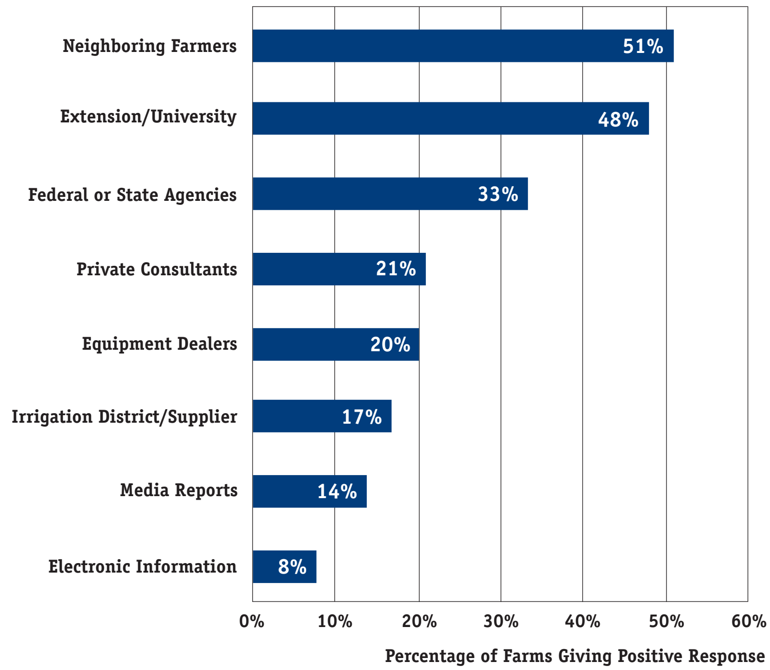


Fig. 6 Sources of Information Relied Upon to Reduce Irrigation Costs or Conserve Water

Online Data Sources

2003 Farm & Ranch Irrigation Survey, Census of Agriculture
www.nass.usda.gov/census/census02/fris/fris03.htm

Water Use in the United States: 50 Years of Water Use Information, 1950–2000
water.usgs.gov/watuse/

Support for this project was provided by the National Oceanic and Atmospheric Administration (NOAA) through the University of Arizona's Climate Assessment for the Southwest (CLIMAS) and was initiated while Dr. Frisvold was on sabbatical leave at the University of Arizona Water Resources Research Center.

A Note on the Cardon Endowment

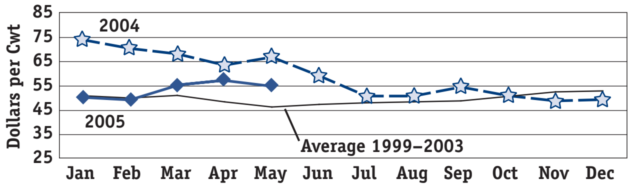
I would like to begin a tradition of updating our readers on the Bartley P. Cardon Endowment for Agricultural and Resource Economics. The Cardon Endowment provides support for the research, teaching, and outreach work of the Department of Agricultural and Resource Economics and was established in 1997 to honor the recently deceased Bartley "Bart" P. Cardon, former professor and dean of the College of Agriculture and Life Sciences.

Cardon Endowment funds are used to support research in agricultural and resource economics by providing resources directly for research, by providing assistantships and scholarships to undergraduates and graduate students, and by bringing national and international scholars to visit the University of Arizona. Much of the research supported by the Cardon Endowment can be accessed from the Cardon Research Papers in Agricultural and Resource Economics, an online repository for scholarly research. The Endowment also supports academic outreach through this newsletter, the *Arizona Review,* a biannual publication providing economic perspectives on Arizona's agriculture and natural resources; the Arizona Agribusiness Forum (just completing its 20th year); and many other activities and publications.

During the past year the Endowment has supported a wide variety of students, scholars, and projects. Student support includes Ph.D. students Carmen Carrion-Flores, Haimanti

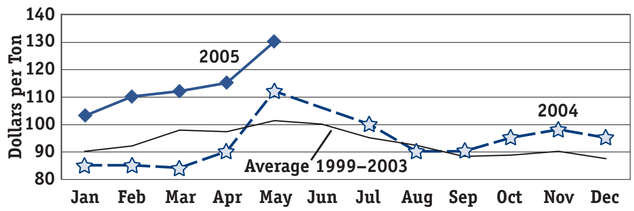
Continued on page 24.

Arizona Upland Cotton Prices



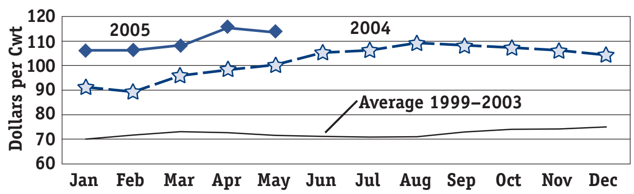
Source: AMS; 31-3-35 cotton prices for desert southwest

Arizona Alfalfa Prices



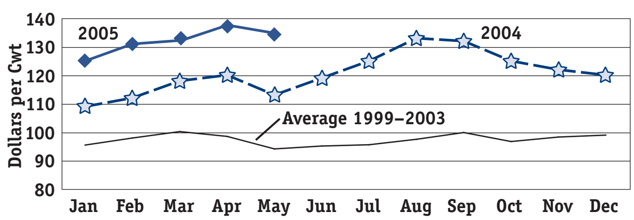
Source: NASS

Arizona Slaughter Steer and Heifer Prices



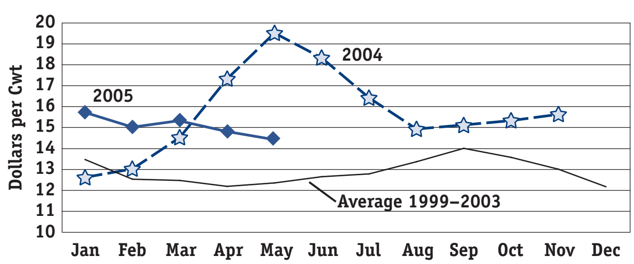
Source: NASS

Arizona Calf Prices



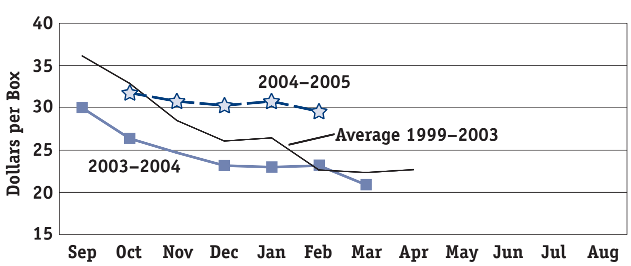
Source: NASS

Arizona Milk Prices



Source: NASS

Arizona Lemon Prices



Source: NASS

Arizona's Agricultural Situation

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U.S. Department of Agriculture (USDA) estimates 13.8 million acres of cotton will be planted in the United States during the 2005–2006 year, up 1 percent from previous year, while in Arizona, plantings are expected to have be about the same. USDA forecasts that U.S. cotton production will decline by 3.8 million bales in 2005–2006 as cotton yields return to a more normal level of 745 pounds per harvested acre. Nationally and in Arizona, 2004–2005 witnessed unusually strong cotton yields. Latest numbers indicate that upland cotton yields averaged 843 pounds per acre at the national level and 1,458 pounds in Arizona. World cotton production is also expected to fall in 2005–2006 with production declines in other major cotton producers: China, India, and Pakistan. Meanwhile, demand for U.S. cotton in 2005–2006 is estimated to increase to 20.8 million bales, a record. While domestic mill use remains at 5.8 million bales, U.S. cotton exports are projected to increase to 15 million bales, a new high. Propelled by China and other Asian countries, global cotton consumption continues to grow. As a result, cotton stocks are expected to decline in 2005–2006 both in the United States and the rest of the world. After a year of declining prices, domestic cotton prices appear to have stabilized in 2005 but remain lower than 2004 levels.

According to the Arizona Agricultural Statistical Service, hay producers are expected to harvest 62.9 million acres of all hay nationally in 2005, up 2 percent from last year. Arizona follows the national trend with 280,000 acres of all hay, a 2 percent increase from 2004. As of May 1, 2005 hay stocks on farms in Arizona were at 35,000 tons, 36 percent lower than 2004 stock levels. Alfalfa hay prices in Arizona have been gaining over the past eight months and remain very strong. Arizona farmers are expected to harvest 2.4 million boxes of lemons for the 2004–2005 year, a drop of 0.6 million from the previous two years. California production, on the other hand, is expected to have increased to 19.5 million boxes, a 1.5 million increase over last year, mostly due to annual yield oscillations. Lemon prices have averaged $30.6/box during the first half of 2005, the highest they have been since the 2001–2002 season and the second highest during the past eight years. Milk prices in 2005 are expected to average considerably less than last year's record but well above the five-year average. During the first five months of 2005, Arizona milk prices averaged $15/cwt, which, while below 2004 levels, is 16.3 percent higher than 1999–2003 average levels.

Cattle markets have breathed a sigh of relief despite USDA's news of the second confirmed case of BSE on 24 June, 2005. There are no real signs that U.S. consumers have reacted negatively to this, and within two weeks future prices have already exceeded the level they were at prior to the announcement. Because the 12-year old cow sampled was born in Texas prior to the 1997 ruminant-to-ruminant feed ban and the cow was headed for pet food, current U.S. policies and safeguards regarding BSE are still in-line with keeping beef safe for consumers.

Relatively low feed prices and higher fed steer and heifer prices are keeping profit margins positive for feedlots. However, improved pasture conditions are resulting in heavy competition for feeders to go in the feedlot or on grass as stocker cattle. This combined with the continuing injunction against live cattle coming down from Canada has resulted in a very tight feeder supply situation, high calf prices, and very limited or even negative expected profit margins for current cattle feedlot placements. Arizona calf prices are at record nominal levels with prices for the first quarter of 2005 14 percent higher than those in the prior year and 31 percent higher than the 1999–2003 average.

Favorable prices and improved range conditions have spawned a noticeable increase in females retained for the cattle breeding herd. U.S. federally inspected heifer slaughter numbers for the first four months of 2005 are about 8 percent below this same period last year. At the same time, federally inspected cow slaughter numbers have been down about 7 percent. Poultry, pork, and sheep sectors are also expanding. January through April 2005 broiler production is up 11 percent from its prior five-year average due to gains in broiler slaughter and bird weights. Sow slaughter numbers are down 5 percent from the prior year, suggesting at least a modest expansion for the pork sector. After decades of year-to-year declines in sheep production, breeding flock numbers are modestly increasing. All of these signals point to lower calf prices down the road, particularly if our beef exports remain suppressed. Given the breeding expansion underway for cattle, poultry, pork, and sheep sectors, fairly conservative calf prices should be used to determine what one can afford to pay for replacement heifers and young bred cows. AR

Harry W. Ayer continued from page 1.

Agricultural Economics Association appointed Dr. Ayer as Editor of CHOICES magazine in 1992. Serving as the second editor for seven years, Dr. Ayer set the quality standard for this quarterly magazine that many still use as a benchmark. European agricultural economists recognized his work with CHOICES and recruited Dr. Ayer to be a co-founding editor of Euro-CHOICES. He also helped found and edit the first two issues of the *Arizona Review* before retiring.

Harry is happily married to Barbara Ayer, with whom he is celebrating forty-one years of marriage. Barbara is a recently retired schoolteacher and together they are enjoying their three sons and daughters-in-law, and two pre-kindergarten grandchildren. I recently caught up with Harry to ask his views on policy issues facing Arizona's agriculture.

Arizona Review. *In the late 1970s you studied the effects of rising energy and water costs on irrigated agriculture. These topics visit the front pages of newspapers today. How have policies to address these issues changed over thirty plus years, and what changes do you see for the future?*

Ayer. In general, energy policy is set at the national level and agriculture is not the main driver of that policy. I hear many of the same kinds of policy proposals now as in the past: open federal lands and coastal zones to exploration to cut our dependence on foreign oil, legislate higher mileage cars and trucks, develop alternative fuels (including more subsidies for corn-based gasohol), and stimulate research and development for greater energy efficiency.

Water costs and water pricing are another matter. Here agriculture is a major player, and both state and federal policies govern water availability and costs to the farmer. Because nearly 100 percent of Arizona's field crops must be irrigated, and most of the water comes from ground or surface sources rather than rainfall, farmers care deeply about policies that affect water costs and availability.

Agriculture still uses a huge proportion—between two-thirds and three-quarters—of all water used in Arizona. By comparison, in most years crop and livestock production contributes about 1 percent to Arizona's Gross State Product, and less than 1 percent of the state's labor force works in production agriculture. Arizona is one of the most urban states, and one of the fastest growing. Our neighboring states—Nevada and California—also have rapidly growing urban populations; the latest census shows that since 2000, eight of the country's ten fastest growing large cites (100,000 or more) are in Arizona, California, and Nevada. These basic facts, coupled with the fact that an acre foot of water for residential and manufacturing purposes is higher valued than in agriculture, lead to a continual pressure to transfer water from agriculture to urban uses.

Part of state/federal water policy revolves around attempts by Arizona, California, and Nevada to maintain or increase their respective legal shares of Colorado

River water. To guard its share, Arizona has subsidized agriculture's use of the water. But drought conditions, coupled with the rapid population growth in all three states, seem to me must eventually lead to policies that will more readily allow for the transfer of water out of agriculture.

Finally, twenty-five years ago the state enacted the Ground Water Management Act of 1980. This act aimed to reduce the groundwater overdraft that characterized water use in much of the state. The act still governs water use, but now as then, it seems to me that the cost of energy needed to pump groundwater has more to do with water use in agriculture than does the act. Most groundwater is pumped from great depths, several hundred feet, and even the Central Arizona Project that brings water from the Colorado River to central Arizona farmers must pump water over 2,000 feet uphill! With high energy prices, pumping is an expensive proposition. It was when the first energy crisis hit in the mid-1970s, and it is now. Perhaps more than changes in water policy, market conditions will force changes in how agriculture uses water.

Arizona Review. *In 1976, Arizona's irrigated crop acreage was just over 1.4 million acres and dropped to around 800 thousand acres by 1983. But crop acreage has been rather steady—around 850 thousand acres—since then. How do you see Arizona's agriculture evolving over the next ten to twenty years?*

Ayer. It will continue to evolve much as in the past. Higher value enterprises will substitute for lower value ones, meaning some specialty vegetables (for seed, comes to mind) and dairy will likely continue to expand and cotton, grains, and ranching to contract. Good management, especially water management, will be rewarded, and poorer management will fall by the wayside. The same is true for technology. Urban growth will continue to expand on agricultural land, using not only the land, but also the water. Exiting farmers will be well paid for their land and water, just as in the past. Indian reservations, winning secure rights to added water, may further expand their agriculture, or they may lease water to urban users. Even though my friend and colleague Jimmye Hillman has argued forever that farmers will always win subsidies from federal farm programs, and he's basically been right for decades, I continue to believe that broader interests will limit these subsidies and further curtail cotton production in Arizona. International trade will continue as a dominant force affecting Arizona agriculture both as an opportunity for export and as competition. Cotton is the prime example of both international competition and export opportunity, but really all our agricultural products are in an international market and subject to supply and demand internationally. Labor-intensive crops like citrus and vegetables will continue to face competition from Mexico and other countries where labor costs less. New regulations under NAFTA to make trucking from Mexico into the United States easier (fruits and vegetables come quickly to mind) will further stimulate this competition. Some Arizona farmers, seeing production advantages in Mexico or even other countries, will move or expand operations there, just as they have in recent years. On balance, I see a smaller agricultural sector for Arizona, with perhaps a few crop and livestock exceptions.

Arizona Review. *With increasing urbanization and a relatively smaller farm population, what important state and national policy issues should Arizona's agricultural leaders address?*

Ayer. Your question implies something that I have long observed: even though Arizona's agricultural sector is relatively small, its industry leaders have been extremely adept at influencing both state and national policy to benefit Arizona agriculture. Some of Arizona's industry groups deliberately "grow" leaders, and that forward-looking action has paid dividends. In view of the ever-increasing importance of non-farm groups, might the agricultural leadership expand efforts to work in harmony with broader interests? To me that is the long run and high ground challenge for Arizona's agricultural leadership.

Arizona's cotton and grain sectors have long benefited from federal farm subsidies. For the most part, federal farm policy did not subsidize the beef, fruit, vegetable, or hay sectors. Europe, too, has subsidized its agriculture, even more so than has the United States. Both of these economic and agricultural trade giants face similar pressures to reform their costly subsidy policies. In the past, agricultural leaders often worked to maintain their subsidies. Perhaps with new and renewed pressures from representatives of a broad range of citizens, taxpayers, less developed countries that see our subsidies impeding their agricultural development, and others, it is a good time to work for an agricultural policy that promotes the broader interest and not just the interest of historical subsidy recipients. For starters, perhaps focus should not be on maintaining subsidies, but reducing subsidies and other impediments to trade on the part of all trade partners. Leaders might also work to find ways to capitalize on the benefits that an urban society receives from the visual amenities (an open, pastoral, not urbanized landscape) that agriculture provides and from which we all take delight.

Given water's importance to both farm and urban users, I see some water law reform helpful to both parties. Currently, groundwater can be transferred among users in the same Active Management Area, or AMA, but not between AMAs. Thus, the fast-growing Phoenix area cannot buy and transfer groundwater from farmers outside the Phoenix AMA. Tucson cannot buy and transfer pumped groundwater from Pinal County farmers, even though the Central Arizona Project canal conveniently connects the two areas.

Arizona Review. *How can the interfacing of technology today (such as GIS, drip irrigation, laser leveling, biotechnology, and communication technology) improve upon land and water use?*

Ayer. Although I did early research (1970s) on the economics of drip irrigation and laser leveling, I don't claim to be a technology expert. But why should that stop me from guessing how new technologies now, or might in the future, improve on land and water use! Yield monitors, combined with GIS (geographic information systems), precisely show low-yield areas of fields. Farmers can check the cause (nutrient condition, poor leveling, clogged or broken drip lines, etc.) and make adjustments, often at lower cost than under older, less precise technologies. Biotechnology has armed farmers with plant varieties that reduce the need for pesticides, some of which harmed off-farm water supplies. Surely communication and computer technologies (cell phones, web-based information) help farmers manage larger units and spread the cost of large-scale equipment, keep up-to-the-minute on market and weather information, and better evaluate new technologies before purchase.

Historically, the United States had an advantage in agricultural technologies. Adopters kept a step ahead of the competition by producing at lower costs per unit of output. That may still be true, but in today's high-tech and interdependent world, new technologies spread fast, and the advantage is short lived.

Arizona Review. *In developing public policy, it is easy for emotions and political agendas to overcome economic logic. What are some basic methods and approaches you have found useful for bringing economic reasoning into a policy debate?*

Ayer. I always felt strongly that economists should best approach policy through the "scientific method." First, carefully define the problem: who and how many have the problem; relatively speaking, gauge the magnitude of the problem. In my view, economists and others get off on the wrong foot if they fail to define the problem at hand. You cannot effectively enter the policy debate if you don't get the problem right. Second, think about policy alternatives. You may end up focusing on one or two, but think through several alternatives early on. Be aware that the policy you evaluate may not be the only alternative. Third, evaluate one or more policy alternatives. This is the place to use sound economic thinking and sound empirical techniques. If your analysis fails to use good underlying economic theory, you're sunk. If you mess up on the statistical analysis, you're sunk. Finally, show the costs and benefits from the policy. Does the policy alternative raise farm income (if low incomes were the problem), and at what taxpayer cost? How many farmers get the higher income? How many do not? Does the policy alternative result in conserved water (if water shortages were the problem), and at what cost to taxpayers? Often times benefits and costs should be put in relative terms to help policy makers—anyone—better gauge the policy's effectiveness.

I like to let the results carry their own policy implication. If prodded to say what policy should be adopted, tell why in terms of the costs and benefits. And one final comment: Economic reasoning can best be brought into the policy debate through communication channels used by the policy makers. Economic results need to be interpreted and presented in a way that can be understood by policy makers or other intended audiences. Journal articles often do not suffice. Use reader-friendly lay publications and presentations.

Arizona Review. *What role do you see for the College of Agriculture and Life Sciences (CALS) at the University of Arizona in helping our state address its natural resources issues?*

Ayer. Resource issues often emerge, sometimes in force, when rural (often agricultural) and urban interests compete for the same resources. Competition for limited water, field dust and chemical drift fowling clean air, feedlot odors, rights to use riparian areas, formerly agricultural land used for unsightly development, and right of way to public lands all come quickly to mind as resource issues heightened by our expanding urban population. The College can and should provide teaching, research, and outreach expertise to help address the issues. Few, if any other, agencies have the resources, expertise, history, and mandate to tackle such issues, and do so in a science-based way. These are often issues of the future as well as the present and the College should train students for these needs. Likewise, the College, through its Cooperative Extension, can and should provide outreach between the University and those affected by resource issues. It seems to me that as the urban sector has expanded relative to the agricultural sector, more College resources have been moved to address such resource issues. I see a continuation of this trend.

Arizona Review. *Do you prefer to be on the giving or receiving end of Arizona Review questions?*

Ayer. It's fun either way! But retirement is better still! AR

Cardon Endowment continued from page 19.

Battacharya, and Arnab Mitra, all working on topics that explore the link between agriculture, land use, and environmental policy; master's student Melissa Burns, working on Arizona's pollution regulations; and undergraduate Sarah McDonald, working on the law and economics of conservation easements. The Endowment supported The 20th Annual Arizona Agribusiness Forum on "Urbanization and Agriculture" and the study *Economic Impacts from Agricultural Production in Arizona* by Jorgen R. Mortenson; Support was also provided for campus visits by Jean Lanjouw, associate professor of Agricultural and Resource Economics at the University of California, Berkeley and Jason Johnston, Fuller Professor of Law at the University of Pennsylvania. Both presented current research in agricultural and resource economics and spent time discussing these projects with faculty and students. Finally, the Endowment proudly supported the program of the 2004 Annual Meeting of the International Society for the New Institutional Economics, an important international meeting of economists focusing on the question of how economic and political institutions can foster or impede economic growth and development.

As you can see, the Cardon Endowment provides vital intellectual and academic support to AREC, CALS, and the UA and it is greatly appreciated. AR

Dean Lueck

For More Information

Cardon Research Papers in Agricultural and Resource Economics
ag.arizona.edu/arec/pubs/researchpapers.html

Arizona Review
ag.arizona.edu/arec/pubs/azreview.html

Arizona Agribusiness Forum
ag.arizona.edu/arec/dept/agbusforum2005/presentations.html

Economic Impacts from Agricultural Production in Arizona
ag.arizona.edu/arec/pubs/econimpacts.html

Dean Lueck *is the Bartley P. Cardon Professor of Agricultural and Resource Economics. Professor Lueck joined the University of Arizona in 2004 and directs the resources of the Cardon Endowment.*

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