



# Agricultural and Resource Economics ARE UPDATE

Giannini Foundation of Agricultural Economics, University of California

Vol. 25, No. 6 Jul/Aug 2022

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## How Are Urban Water Suppliers Responding to Drought?

Mehdi Nemati and Juhee Lee

**In July 2021, Gov. Newsom requested 15% voluntary statewide urban water conservation compared to the same months in 2020. However, thus far, suppliers have reduced water use by about 2% statewide, and only about 5% have complied with the conservation target. This article provides an overview of the urban water suppliers' progress toward the 15% water conservation target and describes their demand management strategies during the current drought.**

Water conservation in California has been a significant concern for urban water suppliers working to satisfy their residential demand while coping with the frequent, prolonged, and severe droughts. One common approach California cities and counties promote for coping with drought is to impose short-term water-use restrictions (voluntary or mandatory). Under such a policy, city officials or water managers inform the utilities' customers that they must bring their water use below some defined threshold, often specified in terms of the customer's historical use.

This type of short-term policy was implemented in California by Gov. Jerry Brown during the 2012–2016 drought. In April 2015, Gov. Brown issued an executive order for cities and counties to take mandatory actions to reduce water usage by 25% statewide from 2013 levels. This was the first mandatory call to reduce urban water use in California's history. In 2020, California faced another major drought, with drought conditions worsening in 2021. On April 12, 2021, Gov. Gavin Newsom declared a drought emergency for water systems along the Russian River watershed.

Then, by May 10, 2021, the governor expanded the drought emergency proclamation to include the Klamath River, Sacramento-San Joaquin Delta, and Tulare Lake watershed counties, covering 39 counties. On July 8, 2021, the governor extended the drought emergency declarations to nine counties, resulting in state-of-emergency directives in 50 California counties. In addition, the governor requested 15% voluntary statewide urban water conservation compared to the same months in 2020.

Finally, by October 19, 2021, Gov. Newsom declared a drought emergency for the entire state of California. The first three months in 2022 were recorded as the driest in history. So, on March 28, 2022, the governor signed an executive order requiring local water suppliers to move to "level 2" of their water shortage contingency plans, meaning a 10%–20% reduction within a district.

### Conservation Achievements From July 2021–May 2022

The California State Water Resources Control Board (Water Board) is the primary agency that adopts regulations to increase water conservation by the urban water suppliers (419 agencies). The Water Board adopted an emergency water conservation regulation in July 2014 that required mandatory reporting of water usage by urban water suppliers. Since the water use accounting began in June 2014, the urban water suppliers covered by the regulation have reported their water usage to the Water Board. The regulation required the state's urban water suppliers to provide monthly water conservation and production reports to the Water

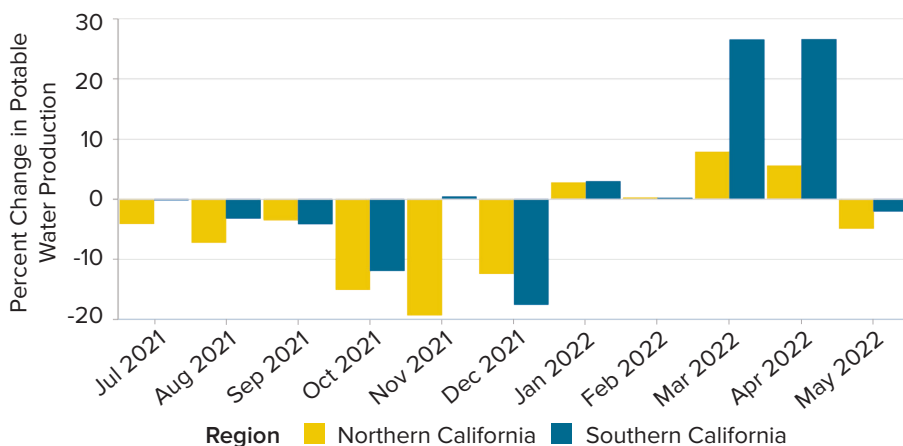
**Table 1.** Potable Water Production and Conservation from January 2020–May 2022

	Number of Suppliers	Baseline 2020 Production (MG)*	July 2021–May 2022 Production (MG)*	Cumulative Conservation (Percent)
California	362	1,551,408	1,520,656	-1.98
Northern California	172	623,862	591,379	-5.21
Southern California	190	927,546	929,277	0.19

Notes: The baseline period covers all the months from 2020, except for June. The conservation period covers July 2021–May 2022 (inclusive). \*Production numbers are in million gallons (MG) and are based on total potable water production, excluding agriculture, in each supplier service area.

Source: Authors' calculations using the reports provided to the Water Board.

Available at: <https://bit.ly/3cDyXJM>.

**Figure 1.** Percent Changes in Monthly Water Production Compared to the Same Months in 2020

Notes: Production numbers are based on total potable water production, excluding agriculture.

Source: Authors' calculations using the reports provided to the Water Board.

Available at: <https://bit.ly/3cDyXJM>.

Board until the emergency regulation expired in November 2017. Since then, most urban water suppliers have continued to report voluntarily.

In May 2018, Gov. Brown signed into law water-efficiency legislation that created water-use efficiency standards and authorized the Water Board to require monthly reports on a non-emergency basis. The water-use reports from urban water suppliers include information on residential water use, total potable water production, measures implemented to conserve water and improve efficiency, and local enforcement actions. The Water Board adopted the monthly urban water conservation reporting regulation, which became effective on October 1, 2020.

Using the reports submitted to the Water Board, we calculated the conservation achievements towards meeting the governor's request in July 2021 for 15% voluntary statewide urban water conservation, compared to the same months in 2020 (Table 1). Statewide, suppliers reduced water use by about 2%, far below the 15% requested by the governor. Of the 362 suppliers reporting, only 20 agencies reduced water production by 15% or more, while 104 increased their production levels.

Although cumulative water conservation is subject to the Water Board regulations, we also look at month-to-month changes in water production (Figure 1). March and April 2022 show

a significant increase in water production in both regions compared to the same months in 2020, with a greater increase in Southern California. The low compliance and the difference in compliance between Northern and Southern California are striking, though it is difficult to attribute these to a single factor.

One primary reason for the increase could be that March and April were drier in 2022 compared to 2020. Subsequently, outdoor landscape irrigation could have increased water demand in Northern and Southern California. An essential feature of the Water Board's request for 15% conservation is the flexibility afforded to individual suppliers to determine how the conservation target will be met. Supplier-level demand management actions such as prohibitions on certain categories of water use, conservation pricing, conservation incentives through rebates for lawn replacement and water-efficient appliances, messaging, and public information campaigns could explain these differences in compliance.

## Who Are Urban Water Suppliers in California?

Community water systems (2,874 suppliers), which are public water systems that supply water year-round to a population, serve more than 97%, or about 40 million, of California's population. The remaining water systems serve very small, transient, or temporary populations. Among community water systems, only urban water suppliers are subject to emergency conservation regulations by the Water Board. These suppliers are defined as those that serve more than 3,000 service connections or deliver more than 3,000 acre-feet of water in a year. 419 out of about 2,874 community water systems in California are categorized as urban water suppliers; they serve more than 91% of the state's population. The urban water

suppliers are further classified by ownership under local government and the private sector (Figure 2).

## Demand-Side Management Strategies During the Current Drought

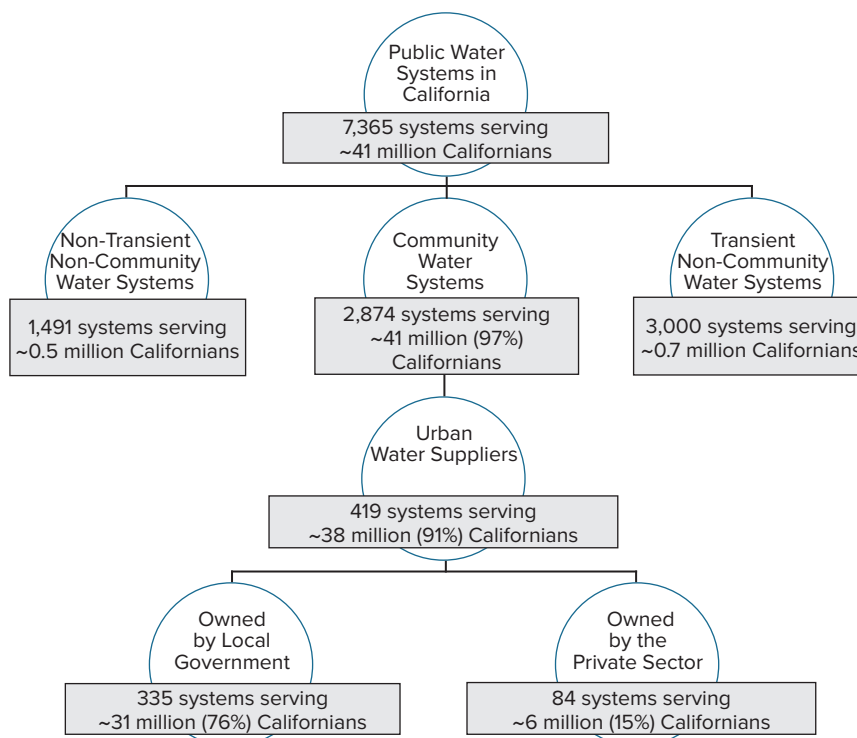
Our analysis of the reports on measures implemented to conserve water indicates that suppliers use one or a combination of the following demand management strategies in the current drought: 1) pricing strategies, such as increasing prices, applying drought surcharges, and reducing allocations for suppliers on budget-based rates; 2) expanding existing rebate programs, introducing turf replacement or removal rebate programs, or both; 3) restrictions (e.g., weekly watering restrictions, use-type restrictions, and application of potable water directly to driveways or sidewalks); 4) water audits; and 5) social norms and customer engagement (e.g., notifications via customer apps, U.S. mail, phone calls, door hangers, radio, television, and billboard advertisements, emails, and social media).

As indicated in Figure 3, in 2020 most suppliers reporting to the Water Board did not enact any demand management strategy. In July 2021, 132 out of the 193 (around 68%) suppliers reporting to the Water Board enacted at least one demand management strategy. The number increased to about 75% in August 2021, and remained roughly the same until May 2022, and then rose to 86% after drought conditions worsened.

## Price and Non-Price Demand-Side Management Strategies

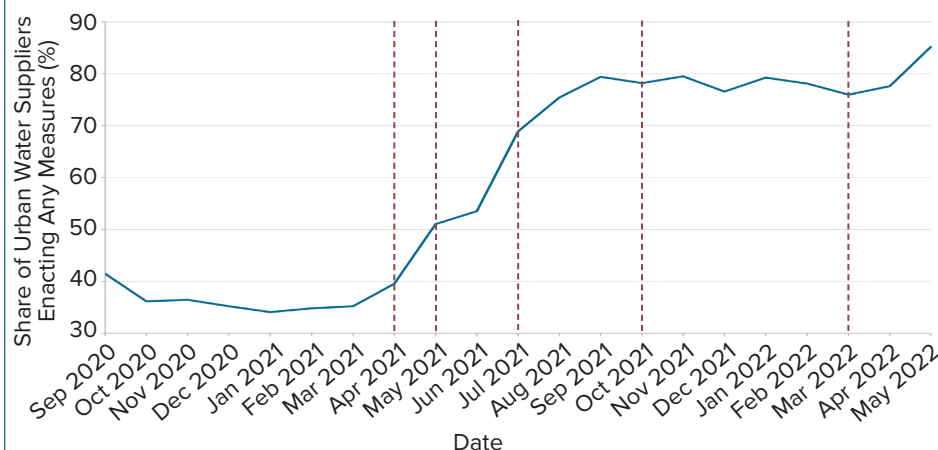
Demand-side management can be defined as a coordinated set of measures to improve water services by inducing changes at the point of consumption, such as changes to pricing, direct financial incentives, regulations, water quotas, and water-use restrictions. In general, pricing methods use market signals to reduce

**Figure 2. Public Water Systems in California by Type and Population Served**



Source: The authors' calculations are based on numbers from the EPA active water systems inventory data. Available at: <https://www.epa.gov/enviro/sdwis-search>.

**Figure 3. Share of Urban Water Suppliers in California That Enacted Any Demand-Side Management Strategy by Month, September 2020–May 2022**



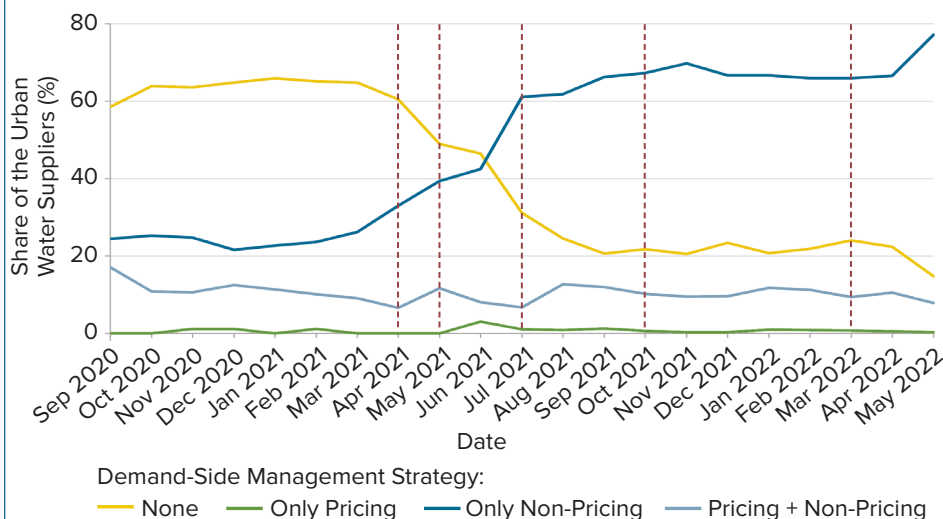
Note: Red dotted vertical lines indicate the major actions taken by Gov. Newsom at the state level. Source: Authors' calculations using the reports provided to the Water Board.

Available at: <https://bit.ly/3cDyXJM>.

water usage. They are more cost-effective than non-price methods, which often encourage behavior through prescriptive approaches. Pricing methods also have the advantage of easier monitoring and enforcement. In some cases, a mixture of price and non-price tools is used according to the needs of the local water utilities.

The percentage of urban water suppliers in California taking demand management actions increased in July 2021, but most of these actions were non-price based (Figure 4, page 4). In May 2022, out of the 359 suppliers who reported, approximately 14% did not implement any demand management action. About 77% enacted only

**Figure 4. Share of Urban Water Suppliers in California That Enacted Demand-Side Management Strategy by Strategy Type and Month**



Note: Red dotted vertical lines indicate the major actions taken by Gov. Newsom at the state level.  
Source: Authors' calculations using the reports provided to the Water Board.

Available at: <https://bit.ly/3cDyXJM>.

non-pricing demand-side management strategies. In this category, a mix of rebates, restrictions, and audits were most commonly adopted (28%), followed by restrictions only (23%), restrictions and audits (14%), and restrictions and rebates (9%). Only a few suppliers (0.29%) relied solely on pricing methods, and about 8% used a mix of pricing and non-pricing management strategies.

## Concluding Remarks

Urban water managers and policy-makers in California are adopting demand-side management strategies to encourage water-use reductions to buffer against short-term water supply shortfalls. During the current drought, there has been low compliance (statewide about 2%) with the 15% conservation target requested by the governor. The primary tool employed is water-use restrictions, either alone or in combination with other non-price methods.

So far, no statewide mandatory water-use restrictions have been imposed, emphasizing the local approach the state has taken to drought management thus far. While it is ultimately

individual suppliers in charge of determining how conservation targets are met, stronger messaging is needed at the state level on the conservation targets that must be met by these suppliers. Voluntary restrictions are less effective in reducing water use than mandatory ones.

Other studies have shown that prohibitions on categories of water use (e.g., landscape irrigation) result in larger reductions than other conservation strategies (e.g., conservation pricing), especially among high-income and high-volume users. More stringent mandatory outdoor watering restrictions combined with pricing measures are the most effective way to achieve the conservation targets. The Metropolitan Water District of Southern California executed an Emergency Water Conservation Program requiring member agencies dependent on State Water Project deliveries to immediately cut water use by implementing one-day-a-week watering restrictions, or the equivalent, by June 1, 2022. Therefore, in June, major suppliers in Southern California, such as the Los Angeles Department of Water and Power

(LADWP), implemented such a policy. While we do not have access to the reports yet, LADWP officials announced that water consumption from city residents plummeted 9% in June compared with the same month last year, and it was the lowest water use for any June on record.

## Suggested Citation:

Nemati, Mehdi and Juhee Lee. 2022. "How Are Urban Water Suppliers Responding to Drought?" *ARE Update* 25(6): 1–4. University of California Giannini Foundation of Agricultural Economics.

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# The Multiple Benefits of CIMIS—Publicly Provided Weather and Irrigation Information in California

Itai Trilnick, Alice Huang, Jed Silver, Ben Gordon, and David Zilberman

We analyze the current uses of the California Irrigation Management Information System (CIMIS), assess the economic gains, and suggest potential strategies for future implementation. We estimate that using CIMIS has led to annual economic benefits of at least \$700 million, of which a significant portion is attributed to water savings in non-agricultural sectors. CIMIS demonstrates the high value of public information that enhances water conservation and increases water-use efficiency.



Economic gains from CIMIS are estimated at \$0.7–\$1.5 billion.

Photo Credit: iStock.

Since the 1970s, California has limited the amount of freshwater available for consumptive use. Despite this limitation and the growing urban population, California's agricultural industry almost doubled the acreage of high-value, water-intensive crops over the past 50 years. One reason for the increased acreage of water-intensive crops is the water savings from water conservation technologies such as drip

irrigation. We propose that the adoption of precision irrigation technologies, enabled by weather information mainly provided through a network of weather stations coordinated by the California Irrigation Management Information System (CIMIS), is another reason for this increase in water-intensive crop acreage.

CIMIS was established by the UC Cooperative Extension in 1982 and is managed by the California Department of Water Resources. There are 263 active CIMIS stations, most of which are in the Central Valley and Central Coast. CIMIS weather stations report local weather conditions and reference evapotranspiration (ET). Growers can then use crop coefficients, established by agronomists, to assess the water use of their crop and determine optimal watering schedules.

While there are many other sources of weather information in California, CIMIS data are unique. CIMIS is a freely available public good and provides historical background and regional comparisons. Data from CIMIS are available online ([www.cimis.water.ca.gov](http://www.cimis.water.ca.gov)).

Despite the usefulness of CIMIS, few studies have quantified its economic benefit. A 1996 study found that CIMIS led to a 13% reduction in applied water, an 8% increase in yield, and a total annual economic gain of \$32.4 million. In this report, we aim to understand the agricultural and non-agricultural uses of CIMIS, identify barriers to increased adoption, and offer potential strategies for future implementation.

CIMIS use has multiple benefits, from water savings in the agricultural

and urban sectors to enhanced yield through more precise irrigation and improved pest control. We estimate that CIMIS generates at least \$700 million annually in economic value, primarily driven by the availability and pricing of water on the margin. A large share of CIMIS's economic benefits is in non-agricultural sectors. Therefore, failure to account for spillovers in CIMIS use may result in under provision of this information source. Due to limitations inherent in any large-scale survey, we only quantify CIMIS's value in some key areas and leave other areas (e.g., research, policy, and commercial uses) to future research.

## Methodology

This study uses qualitative interviews and quantitative survey methods to estimate the economic value of CIMIS among the most significant users of the website. Pre-survey interviews with experts were conducted to obtain information to complement the survey findings. A comprehensive online survey was sent to registered CIMIS website users to assess the narratives, benefits, and value of CIMIS across major user groups. Restricting our analysis to the largest CIMIS users is more relevant and less expensive for estimating CIMIS's economic benefits relative to establishing a census or representative sample.

In total, we conducted 179 interviews and collected 2,358 completed survey responses. About one-quarter of survey respondents listed their primary user type as "agriculture", followed by "other" (15%), "government" (13%), "research" (12%), and "environmental design/consulting" (10%). Most respondents (80%) reported only one area of activity.

**Table 1.** Estimated Water Savings Attributed to CIMIS Data by Sector

Sector	Mean	Standard Deviation	Observations
Percent			
Agriculture	24	14	201
Consulting	23	13	154
Golf Courses	21	14	28
Government	21	9	66
Landscaping	30	13	137
Research	25	14	62
Water District	23	18	44

Source: Based on author calculations using data from the online survey.

## Major Findings

CIMIS has become a mainstay in agricultural systems, especially those relying on drip irrigation. However, many farmers access CIMIS data indirectly through consultants and may not be fully aware of CIMIS's data offerings and benefits. Within agriculture, CIMIS data are mainly used to improve irrigation performance, calculate fertilizer and pest application timing, and determine crop water allocation and watering schedules. The most used measures of CIMIS data offerings include ET and precipitation. Agricultural experts also use historical CIMIS data to model irrigation and design drainage systems.

While agricultural users report the highest use of CIMIS, this study also finds that CIMIS use extends beyond agriculture, especially in the urban sector, for the irrigation of urban landscapes. CIMIS is also used for regulatory purposes, such as managing water allocations and pricing urban water. In primary and applied research, CIMIS has contributed to research topics ranging from climate and hydrology to agriculture and renewable energies. The overall perceived importance of CIMIS is also high, with 85.4% of respondents who report using CIMIS assigning the service a "medium" or higher (rank 3+) importance for their operations.

Several factors, however, hinder the use of CIMIS. Approximately one-third of users cite distance from the nearest CIMIS station as the main limitation. Many growers and consultants also report challenges complementing CIMIS data with data from other sources. A large share of respondents (43%) indicate that they would be interested in further training on ET and other data applications, which suggests that informational asymmetries may also be a barrier to adoption.

Across all users, the primary benefit of using CIMIS is water savings. We estimate water savings across all sectors ranging from 21%–30%, with agriculture, the largest group in response size (and water use), reporting average water savings of 24%. Table 1 shows the estimated water savings by sector.

## Valuation of CIMIS Services

Our goal is to estimate the value of CIMIS based on the estimated savings across the service's most prominent users. Quantifying the value of CIMIS requires assumptions on critical parameters and counterfactuals of how agricultural systems would function in the absence of CIMIS, which are informed by previous studies and interviews with experts. We separately examine the economic benefits of CIMIS data in water savings, yield, and quality effects across agricultural and non-agricultural user groups.

## Economic Benefits in Agriculture

**Water Savings:** CIMIS use leads to water savings primarily through enabling the adoption of precision irrigation technologies, such as drip irrigation. Growers and agricultural consultants in our survey report an average water-saving effect from using CIMIS data of 24% and 21.5%, respectively. We take the lower estimate as agriculture's (conservative) water-saving effect. Using the 2013 USDA Farm and Ranch Irrigation Survey's estimates of 2.8 million acres of drip irrigated land in California and an average value of 2.5 acre-feet (AF) of water per acre, we estimate the total annual water use for drip-irrigated acreage to be 7 million AF. Thus, using the water saving rate of 21.5%, the amount of water saved by growers who use CIMIS is 1.92 million AF per year.

The net economic value of the water saved using CIMIS data is the sum of expenditures that growers would incur if they purchased the water. Assuming a perfectly inelastic demand for water, which is reasonable in the short term, we multiply the amount of water saved by the price of water. However, water prices in California vary over time and space, making it difficult to determine a single benchmark price for this calculation. Following Taylor, Parker, and Zilberman, we use a range of water prices, \$80–\$220 per AF, to assess the monetary gains from water savings. For the 1.92 million AF of water saved using CIMIS data, the price range implies annual monetary savings of \$154–\$422 million. Monetary savings could be even higher in drought years when water prices reach \$1,100 per AF.

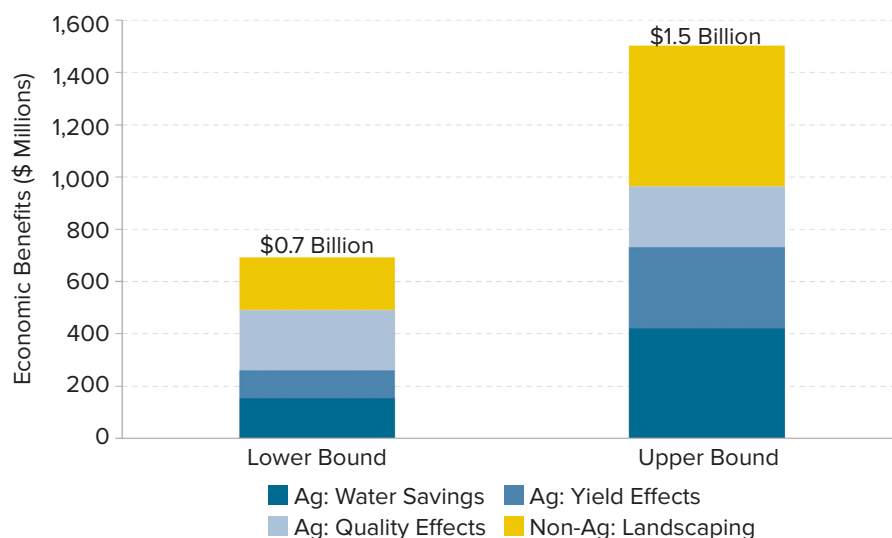
**Yield Effects:** Since CIMIS allows for more precise irrigation, we also expect yield effects as water application is adjusted to crop requirements. We asked growers to rank how CIMIS data contributes to increasing yields,

from 1 (“none”) to 5 (“a lot”). Previous studies and interviews with experts estimate the average yield effects of drip irrigation to be between a 5% and 25% increase in output. For a lower-bound estimate, we assume rankings between 1–3 signify a 0% yield effect, and rankings of 4–5 signify a 5% increase in yield. For a higher-bound estimate, we assume rankings of 1 signify a 0% yield effect, rankings of 2–3 signify a 5% yield effect, and rankings 4–5 signify a 10% yield effect.

Using these assumptions, we estimate that CIMIS increased crop output (supply) between 2% and 5.9%. The higher output tends to reduce prices. We assume an elasticity of demand of -2, suggesting that a 1% increase in output reduces prices by 0.5%. We also use the weighted average crop value per acre in 2016 of \$3,757 per acre, which is slightly lowered due to the increased supply. After adjustment, the yield increase leads to an additional annual income of \$38–\$111 per acre for growers. For the 2.8 million acres with drip irrigation, the annual contribution of CIMIS to yields is approximately \$107–\$311 million.

**Quality Effects:** Weather data can have quality effects on crops. For instance, using ET data and drip irrigation can increase the quality of tomatoes, leading to increases in the price received by growers. To assess this measure, we asked respondents to rank the contribution of CIMIS to quality from a rank of 1 (“none”) to 5 (“a lot”). Based on the experts’ suggestion, we assume that a ranking of 4–5 corresponds to a quality index resulting in a price increase of 5%. Furthermore, based on previous studies, we assume that the average price increase due to a 1% increase in crop quality is \$37.70 per acre. Approximately 45% of agricultural respondents report rankings of 4 or 5. Therefore, the average price increase due to quality improvements is 2.2%, or \$83 per acre. The 2.8 million

**Figure 1. Summary of Economic Benefits from CIMIS (Lower and Upper Bounds)**



Source: Based on author calculations using data from the online survey, previous studies, and interviews with experts.

acres corresponds to an increased revenue of \$231 million. In total, we estimate that the monetary value of CIMIS on water savings, yield, and quality improvements in agriculture is between \$492–\$964 million.

However, an alternative approach to assess the economic benefits of water savings in agriculture using CIMIS is to estimate the value of the agricultural output that could be produced with the water savings. As mentioned previously, California was able to increase the acreage of water-intensive, high-value crops without using extra water. With 1.92 million AF of annual water saved due to CIMIS and an average use of 2.5 AF of water per acre by growers (assuming the water goes to drip-irrigated crops), the savings from CIMIS are equivalent to adding the production of a hypothetical 768,000 acres in California.

To value the output that can be produced with the water savings, assuming that the “added land” replicates the existing distribution of crops, we multiply the \$3,757 per-acre income estimate for growers by 768,000 acres, resulting in \$2.89 billion in extra revenue. This estimate needs to be corrected for the reduction in price due to

the -2 elasticity of demand for California crops. Thus, the resulting additional revenue for growers is approximately \$1.44 billion. This increase in revenue is larger than the increase in net income. While we do not use this figure in our final assessment, this figure provides another indicator of the magnitude of the agricultural value gained from CIMIS.

### **Economic Benefits in Non-Agriculture**

**Landscaping and Golf:** Respondents in landscaping and golf reported a total annual water savings from using CIMIS of 220,707 AF. Water prices for this user type are much higher relative to agriculture, and thus the incremental gains from CIMIS are higher. We construct bounds for our estimate using various municipal water rates: for the Los Angeles Department of Water and Power (LADWP) non-profit rate, which is as low as \$2.10 per 100 cubic feet, the value of water savings amounts to \$201.4 million per year. LADWP also charges commercial, industrial, and governmental water users by tiers, with rates of \$5.26 and \$8.67 per 100 cubic feet for tiers 1 and 2, respectively, as of January 2019. Assuming we are in Los Angeles and



90% of the water consumption is in tier 1, the total water savings is \$539 million.

Figure 1 (on page 7) provides a summary of the quantified economic benefits of CIMIS. We estimate the annual economic gains from using CIMIS to be between \$0.7–\$1.5 billion. As previously mentioned, quantifying our qualitative survey findings presents many challenges but suggests considerable economic benefits due to CIMIS. Furthermore, the quantified benefits only represent a subset of total benefits. For instance, gains from research, regulation, and other activities are not quantified and are likely sizable in magnitude.

Relative to the 1996 report, we find the economic gains to be considerably greater in value. This difference may be due to several factors. Since 1996, not only have water prices in California increased substantially, but in response to droughts and new technologies, there is also a greater use of CIMIS and smart irrigation planning in agricultural and urban sectors. While our estimated water savings attributed to CIMIS are large in absolute terms, in proportional terms, this amount only represents 8.2% of the total water used for irrigation in California in 2013. Similarly, the agricultural economic gains we attribute to CIMIS account for around 1%–2% of California's agricultural income.

## Discussion

Our findings suggest that CIMIS data generate at least \$700 million annually in economic value, of which a significant portion is attributed to water savings in non-agricultural sectors. Though we do not analyze the operating costs of CIMIS, the gains detailed in this report far surpass these operating costs. These findings also reflect the evolution of CIMIS's importance to a wide variety of users, which may continue to grow over time. Our research shows how valuable publicly

available, research-based information can be in allowing the California agribusiness community to maximize their resources.

California agriculture has changed substantially since the establishment of CIMIS, and many of its current uses are evolving. Having started primarily as an irrigation assistance service, CIMIS is now used in pest management, supply chain operations, and even in sectors beyond agriculture. As California faces the ongoing challenge of climate change, information sources such as CIMIS have become more important for increasing water-use efficiency.

However, CIMIS needs to modernize. At present, CIMIS faces two main challenges. The first is the proliferation of private, low-cost weather stations, which may decrease demand for CIMIS. It is unclear, however, how much growers need data from private stations, given the availability of CIMIS data. CIMIS remains the most important provider of ET data, which are valuable to growers. In particular, CIMIS's Spatial ET service provides more accurate approximations of local climate. Furthermore, CIMIS's broad coverage and historical information complement other weather networks and provide verification of private weather data. Private stations also do not give the positive social externality of making the information publicly available.

The other main challenge for CIMIS in agriculture is the accessibility of its website. We strongly suggest enhancing the CIMIS web interface to allow integration with other agro-climatic and economic information sources. Further, we recommend that future research also explore the role of CIMIS as part of the weather information ecosystem, with the aim of combining weather and spatial data and agro-economic information to improve decision-making.

## Suggested Citation:

Trilnick, Itai, Alice Huang, Jed Silver, Ben Gordon, and David Zilberman. 2022. "The Multiple Benefits of CIMIS—Publicly Provided Weather and Irrigation Information in California." *ARE Update* 25(6): 5–8. University of California Giannini Foundation of Agricultural Economics.

## Authors' Bios

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# Does Better Information Increase Fishery Profits?

Gabriel Englander, Larry Karp, and Leo Simon

**In the world's largest fishery, we find that better information about the location and size of fish populations would decrease fishery profits. This counterintuitive result occurs because the congestion costs arising from vessels fishing in the same places and times are large.**



Increased information sharing among Peruvian fishing vessels would lower fishery profits.

Photo Credit: iStock.

Like cars on the highway, vessels can cause congestion at sea when too many of them fish in the same place at the same time. They also leave fewer fish in the water for others to catch, further lowering profits. Better information enables vessels to fish in more productive locations. But it may also increase congestion costs by causing vessels to converge on the same location. We develop a theoretical model to determine whether the benefits of better information—fishing in more productive locations—exceed the increased congestion costs. We estimate our model with data from Peru's anchoveta fishery, which accounts for 8% of global marine fish catch and is the world's largest fishery.

Governments have the ability to improve the information available to fishers. For example, Peru's fisheries ministry has the ability to publish near real-time data on catch by all

industrial anchoveta fishing vessels. But if doing so would decrease industry profits, then regulators should maintain their current policy of not publishing these data.

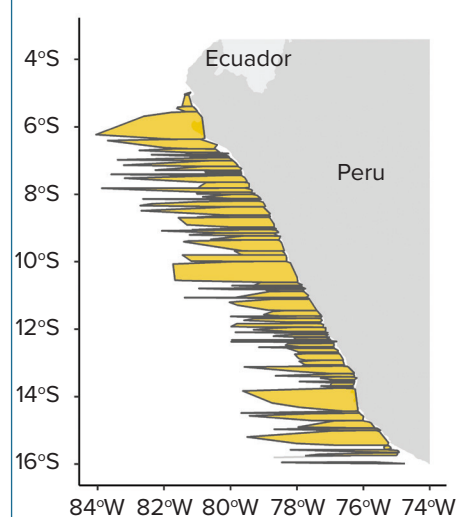
Peruvian anchoveta fishers use public and private information to choose where to fish. Public information includes satellite data on chlorophyll and sea surface temperature, which fishers use to predict the locations of anchoveta. Private information includes the catch of vessels that belong to the same firm. Improvements in both types of information help fishers find better fishing locations but also increase congestion. Improved public information is particularly likely to increase congestion because it is shared with everyone, while private information stays within the firm. For this reason, improvements in private information are more likely to increase profits than improvements in public information. In general, both types of information might raise or lower profits.

Our data include the location, time, and tons that vessels catch each time they "set" their net in the water (see Figure 1 for a map of the fishing zones). There are 246,920 sets reported by 806 unique vessels in the data. We adjust tons caught by vessel characteristics to create a measure called Catch Per Unit Effort (CPUE). CPUE accounts for the fact that fishing by larger and more powerful vessels requires more energy than fishing by smaller and less powerful vessels.

Figure 2 plots CPUE by location. We use CPUE as a proxy for vessel profits and for the productivity of different fishing locations each day. We do so by regressing tons per set on the length (in meters), engine horsepower, and gross tonnage of each vessel. The

residuals from this regression are our preferred measure of CPUE because they are catch conditional on effort.

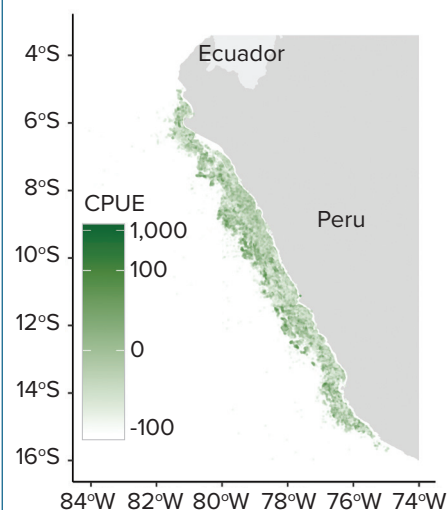
**Figure 1. Anchoveta Fishing Zones**



Note: The distinct regions show the different fishing zones in our data set; all vessels are prohibited from fishing within 5 nautical miles (9.3 km) of the coast.

Source: Englander, Karp, and Simon. 2022.

**Figure 2. Peruvian Anchoveta Fishery Data, 2017–2019**



Notes: Each point is a vessel-level fishing operation, called a set. The color of each point is the catch per unit effort (CPUE) of that set, which we calculate by adjusting tons caught by vessel characteristics.

Source: Englander, Karp, and Simon. 2022.

A fisher's payoff—their CPUE—increases when they fish closer to the “ideal location,” where the stock is densest. The payoff also increases with the dispersion of vessels, as this lowers congestion. A fisher's expected payoff in our model depends on three parameters: the relative precision of public versus private information about the ideal location; the correlation between the public and the private information; and the importance of being close to the ideal location, relative to the importance of being far from other vessels.

The first parameter is a measure of the relative quality of the two types of information. The second parameter, which is not present in earlier models, further describes the relation between the two types of information, and is critical to our empirical results. The third parameter measures the importance of congestion. Our model allows for the possibility that there are “negative congestion costs,” i.e., vessels benefit from the proximity to other vessels, possibly because of improved safety. However, our data imply that congestion costs are positive and large.

We determine whether better public or private information would increase profits in two steps. First, we estimate the relative precision of public and private information and the correlation between public and private information. Then we estimate the benefit of fishing closer to the most productive location relative to the cost of congestion.

### Relative Precision and Correlation of Public and Private Information

The relative precision of public and private information and the correlation between public and private information determine how fishers translate public and private information into decisions on where to fish. If information is more precise, it is more

likely to guide fishers to the most productive fishing location. Relative precision refers to a comparison between the precision of public information and the precision of private information. If public information is more precise than private information, then fishers know that it is a stronger predictor of the most productive fishing location. The correlation between public and private information informs how fishers anticipate each other's decisions. If they are highly correlated, then private information is effectively less private. Fishers still have private information, but it is similar to the public information that all fishers receive. An improvement in private information, in this case, is less likely to increase profits because it will cause more congestion than if the correlation was lower.

We identify the best fishing location each day with CPUE data, and we estimate how well public and private information predict this location. We find that public information is slightly more predictive than private information; it is relatively more precise. We also estimate a high degree of correlation between public and private information.

### Benefit of Fishing Closer to the Best Location Relative to the Cost of Congestion

We estimate the relationship between CPUE, our proxy for profit, and two variables: the distance to that day's best location and congestion. We measure congestion as the distance to all other sets (vessel-level fishing operations) that day. Congestion is lower when the distance to all other sets increases. We find that a one standard deviation increase in congestion decreases CPUE by 2.37 tons (0.05 standard deviations of CPUE), while a one standard deviation decrease in distance to that day's best location increases CPUE by 4.23 tons (0.08 standard deviations). These results

demonstrate quantitatively the countervailing effects of better information: higher profits from vessels fishing in better locations but lower profits from more vessels fishing in the same locations.

### A Negative Value of Public and Private Information

If we simply ignored the correlation between public and private information, then our point estimates for the cost of congestion relative to the benefit of being close to the ideal location, and of the relative precision of public versus private information, would imply that improved public information lowers profits, but improved private information raises profits. Our estimates would then imply that congestion costs are in an intermediate range, high enough that the value of improved public information is negative, but low enough that the value of improved private information is positive.

However, we find that public and private information are highly correlated. Including this correction, our estimates imply that greater precision of both public and private information would reduce profits. If Peru's fisheries ministry continuously published their near real-time catch data, fisher's profits would decrease. Improvements to private information, e.g., due to subsidizing onboard fish finder technology, would also reduce fisher's profits, but by a lower amount. Additional information-sharing among vessels, converting private to semi-public information, would also likely lower profits.

### Discussion

These counterintuitive results occur because our model and statistical analysis emphasize the possibilities of congestion, distinguish between public and private information, and allow correlation between public and private information. Our paper demonstrates

the surprising result that better public or private information reduces profits in the world's largest fishery.

A large body of empirical literature documents circumstances where better information enables a decision-maker to increase profits or welfare. However (to the best of our knowledge) all of these papers consider situations where better information enables a decision-maker to adopt better plans, but without otherwise affecting the environment in which that agent operates. In contrast, we consider the equilibrium effect of better information, which takes into account the effect of better information on all vessels' behavior.

A single vessel in our setting would certainly be able to improve its payoff if it were the only vessel receiving the improved information. However, when all (or more generally, many) vessels receive better information, their collective decisions change. Each vessel responds optimally to maximize its own profits. When congestion is important, vessels create a "negative externality," i.e., their individually rational actions reduce collective welfare. Better information increases that negative externality.

An example helps to clarify the distinction between individual and equilibrium effects. Suppose that a regulator attempts to control firms' pollution emissions, but can observe the firms' decisions only imperfectly. If the regulator is suddenly able to observe firms' decisions more precisely, and if there is no change in firms' behavior, then the more precise information certainly benefits the regulator. In that example, the better information changes the regulator's decisions, but not the environment in which she operates.

However, firms might change their behavior once they recognize that the regulator has better information; in that case, we would be interested in

the equilibrium (i.e., "overall") effect of the better information. If the regulator's improved information makes firms decide to follow emissions rules more carefully, because firms now think that there is little chance that they will be able to get away with breaking the rules, then the equilibrium effect of the better information amplifies the direct benefit that takes into account only changes in the regulator's behavior. Alternatively, if firms decide to increase their anti-regulation lobbying or engage in other individually rational, but socially costly, means of evading the rules, then the equilibrium effects would reduce or might even overturn the apparent benefits of better information.

This example illustrates the important point that sometimes we know neither the direction nor the magnitude of the equilibrium effects of a change that (at first blush) seems to improve welfare. It is analytically convenient, but possibly quite misleading, to simply ignore these potential equilibrium effects. The example also illustrates the difficulty of using results from one context to inform policy in another setting.

Our empirical results for the Peruvian anchoveta fishery provide a high level of confidence in the conclusions that better public or private information would lower fishery profits, and that increased information sharing among vessels (converting private to semi-public information) would also lower profits. Our model and estimation procedure can be useful for other fisheries, and other natural resource settings where congestion may be important. However, we do not recommend applying our policy conclusions to other settings, without context-specific analysis of those settings.

#### **Suggested Citation:**

Englander, Gabriel, Larry Karp, and Leo Simon. 2022. "Does Better Information Increase Fishery Profits?" *ARE Update* 25(6): 9–11. University of California Giannini Foundation of Agricultural Economics.

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#### **For additional information, the authors recommend:**

Englander, Gabriel, Larry S. Karp, and Leo K. Simon. 2022. "The Value of Information in a Congested Fishery." Available at SSRN: <https://bit.ly/3aAID7n>.





Agricultural and Resource Economics

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**Published by the**  
Giannini Foundation of  
Agricultural Economics

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