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Special Issue: Implications of the Drought for California Agriculture

California is no stranger to drought, yet each drought is different, bringing unique consequences and adaptations. This past year was exceptionally hot and dry, and no sector has been affected more than agriculture. In this special issue of *ARE Update*, we explore aspects of the current drought and what it means for California agriculture.

In the first article, John Abatzoglou, a climatology professor at UC Merced, sets the stage by characterizing this drought relative to historic droughts. The article confirms that the 2020–21 drought has been unusually severe overall and has affected pastures and Northern California more than other recent droughts. Abatzoglou documents changes in evaporative demand, showing just how thirsty the atmosphere has been this last year. In doing so, the article also provides great perspective for thinking about future droughts and water scarcity under climate change.

California farmers and ranchers make adaptations in response to drought that mitigate negative impacts on food supply chains, prices, and farm revenues. In the second article by Daniel Sumner, Carlyn Marsh, Quaid Moore, Scott Somerville, and Josué Medellín-Azuara, the authors document acreage and livestock responses by farmers and ranchers. They highlight adaptations like using additional groundwater, cutting other acreage to keep trees and vines alive, and shifting water to crops that yield a higher expected net revenue per drop. They also provide data on land reallocation and cropland left unplanted.

In our third article, Daniel Sumner, Elizabeth Fraysse, Scott Somerville, and Josué Medellín-Azuara show that, despite a severe drought and hundreds of thousands of acres of field cropland left idle this year, effects across regions and crops are uneven. Many crops, especially coastal fruits and vegetables, have had little reduction in supply in this drought. Indeed, in 2021, California farm revenue may actually rise, not fall. The authors explain that this is because of price increases driven by global supply and demand conditions, such as high feed grain and oilseed prices in the Midwest, higher beef and milk prices, and strong demand for tree nuts, fruits, and vegetables.

The final article rounds out the issue by discussing how we can improve our water system to better adapt to future droughts. Ellen Bruno uses the findings in the previous articles to evaluate how improvements in economic policy governing irrigation water would allow us to make better use of the water we have. She considers policies for both surface and groundwater and argues that we can move water more effectively from year to year through more effective use of groundwater storage. Even if droughts do not increase in the future, warmer winters mean we will need to improve storage to deal with less snowpack.

Special Issue Editors
Ellen M. Bruno
Daniel A. Sumner

ALSO IN THIS ISSUE

Climatological Context for California's Ongoing Drought

John Abatzoglou

Back-to-back hot-dry years have left California parched. By late summer of 2021, half of California found itself in an exceptional drought. I review the climatic factors that led us into this deficit and provide its context relative to some of the state's most notorious droughts. Increasing atmospheric thirst, together with climate change, has arguably supercharged recent droughts, including California's ongoing drought.

The Sacramento basin had the lowest precipitation and highest evaporative demand in the past four decades for the 2021 water year.

Photo credit: Juan A. Salgado/ Shutterstock.com

California's climate is defined by wild year-to-year variability in precipitation. An average water year in terms of accumulated precipitation is quite rare in California. Many of the state's ecosystems are adapted to such volatility. Further, state infrastructure—including reservoirs and water conveyance systems—has been designed to cope with historical droughts. Recent droughts, however, have tested many of these systems. In some cases, these droughts have catalyzed adaptation responses, as well as mitigation efforts, to provide a buffer against future droughts. Nonetheless, recent drought impacts have materialized in diverse sectors including widespread tree mortality in the Sierra Nevada, rapid groundwater depletion that has resulted in dry wells and agricultural challenges in the Central Valley, and combined low-flows and warm river temperatures decimating salmon populations in the rivers of Northern California. The ongoing drought presents another stress test for the state and likely will facilitate further adaptation plus mitigation efforts for future droughts.

The Ongoing Drought

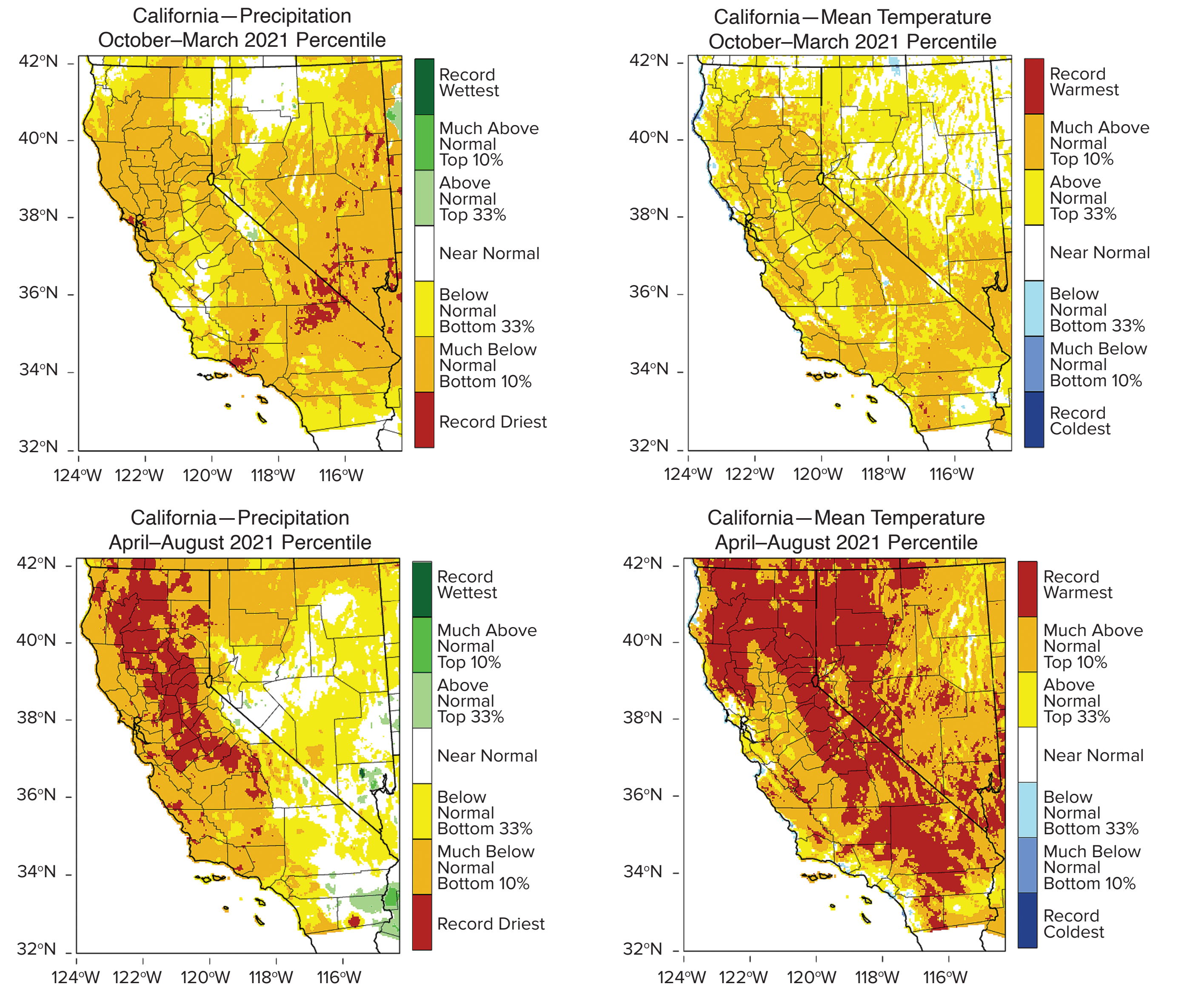
When did the ongoing drought start? A historic multi-year drought commenced during the 2012 water year (October 2011–September 2012). Several studies showed that the multi-year drought was not only the most extreme in the modern climate record but also the most extreme in at least the last 1,200 years based on tree-ring data. Although the state had a couple of very wet years in 2017 and 2019 that ameliorated drought impacts (e.g., reservoir levels), it is debatable as to whether a couple of wet years "ended" the drought based on other lagging indicators such as groundwater levels and vegetation mortality. For this writeup, I will focus on the ongoing drought beginning with the 2020 water year.

The 2020 water year was dry and hot. Statewide precipitation was 68% of 20th century averages, with higher deficits in the Sacramento basin (60% of average). The state had its warmest April–September since 1895, with temperatures nearly 3.5ºF above the 20th century average. Record-setting warmth, combined with dry conditions, allowed for an extra 3–4 inches of evaporative demand (the amount of potential moisture pulled by the atmosphere from a well-watered land surface, sometimes referred to as potential evapotranspiration) relative to average levels for the late 20th century.

These conditions set the stage for moisture-starved soils and vegetation with the commencement of the 2021 water year. The storm track door remained sealed through early November, as the jet stream that is a highway system for storms remained well north of the state. A few meager storms visited the state throughout the winter. Davis, California saw only 16 days with meaningful precipitation (daily totals of at least a tenth of an inch)—tying a water-year record for futility with the infamous 1977 water year. Notably absent were strong atmospheric rivers. The presence or absence of atmospheric rivers can make or break a water year, as such events contribute up to 50% of the annual precipitation in parts of the state. A moderate atmospheric river in late January brought solid precipitation totals along the central California coast and into the central Sierra Nevada. This system brought significant lower-elevation snowfall accumulations, with locations like Calaveras Big Tree State Park receiving a record 76.5 inches of snowfall in a three-day period. This event softened the mounting precipitation deficits in the San Joaquin basin.

A persistent ridge of high pressure in the northeastern Pacific kept the storm track well north of the state, and continued through the remainder of the winter. By the end of March,

Figure 1. Temperature and Precipitation Rankings for Water Year 2021



Note: (Top row) Rankings of October 2020–March 2021 cumulative precipitation and mean temperature relative to the 1895–2021 period. (Bottom row) Rankings of April 2021–August 2021 cumulative precipitation and mean temperature relative to the 1895–2021 period.

Source: West Wide Drought Tracker. Available at http://www.wrcc.dri.edu/wwdt/.

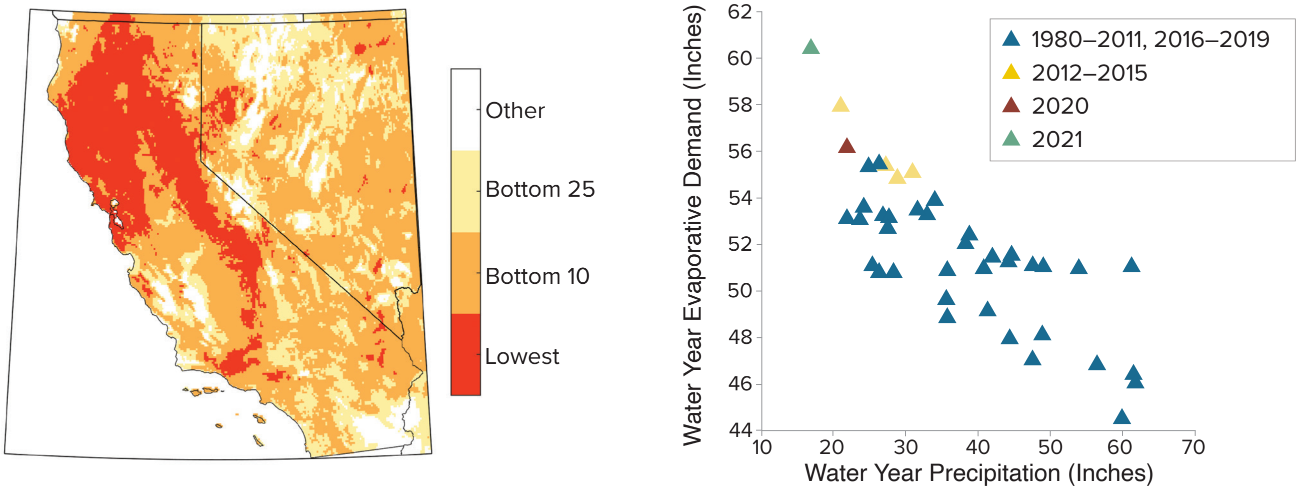
most of the state had well below-average water-year precipitation, with a few isolated locations in Ventura and Marin counties having their driest start to a water year since at least 1895 (Figure 1). Autumn and winter temperatures were warm, but not unusual in the context of the past couple decades for the state. Consequentially, late winter snowpack (60% of average) largely reflected precipitation deficits. The snow drought was not as acute as in recent winters, such as water year 2015 that saw below-normal mountain precipitation and extremely warm winter temperatures. By early April, nearly all of the state was in drought—per the U.S. Drought Monitor—with about 5% in exceptional drought. Snowpack decreased rapidly in April, with the onset of anomalously warm temperatures. Unfortunately, the decrease in spring snowpack was not well reflected in spring streamflow, leading to a sizable reduction in state water resource allocations. It is hypothesized that snowmelt infiltration into parched soils reduced the amount of water available for runoff.

Spring continued the streak of months with below-normal precipitation. Record low April–August precipitation was seen for much of the western slopes of the Sierra Nevada northward into the Klamath basin (Figure 1). Just as the storm track door opened late in autumn, it closed early in the spring. Statewide, the 2021 water year was the third driest since 1895 and the driest since 1977—receiving about half of the 20th century average rainfall (47% of average in the Sacramento basin). Cumulative precipitation deficits since

Figure 2. Drought Rankings for Water Year 2021

a. Rankings of July 2021 PDSI Relative to the 1895–2021 Period of Record.*

b. Scatterplot of Water Year Precipitation and Evaporative Demand for the Sacramento Basin for 1980–2021.



Note: *Red denotes the lowest PDSI on record, with orange and yellow denoting PDSI values in the lowest 10 and 25 years on record, respectively.
Source: West Wide Drought Tracker, gridMET. Available at: http://www.wrcc.dri.edu/wwdt/.

October 2019 have left parts of the state missing more than a year's worth of precipitation. Such numbers have been reflected in low—and in some cases record-low (Oroville)—reservoir levels by late summer.

Some have viewed drought as being entirely driven by precipitation shortfalls. This view presumes little change in drought in California after April, given the nominal precipitation that falls from May–September. However, the data do not bear out that view. Between early May and late August, the percent of the state in exceptional drought rose from 5% to nearly 50%. Drought isn't defined solely by water supply. The demand side can be particularly important. Climate-based drought monitoring typically considers some type of demand in addition to precipitation.

Significant increases in evaporative demand have been observed across California and much of the western United States over the past several decades. Evaporative demand in 2021 for much of Northern California is the highest it has been in at least the last four decades—over 8 inches above the late 20th century average.

A combination of dry conditions and low cloud cover in spring, and record-setting summer temperatures, were responsible for a very thirsty atmosphere. This exceptional atmospheric thirst has further taxed sparse soil and vegetative moisture, allowing for worsening drought conditions.

Benchmarking the Ongoing Drought

Where does this drought rank relative to many of the state's infamous droughts? The answer depends on how we define drought. Based on the Palmer Drought Severity Index (PDSI)—a widely used drought index that tracks normalized soil moisture anomalies based on precipitation and evaporative demand—July 2021 values set records for much of Northern California (Figure 2a). Most of the rest of the state had PDSI values in the ten driest years; conditions in 2014 were more acute in the San Joaquin and Tulare basins. PDSI values for the Sacramento basin during July 2021 were the lowest since at least 1895—topping individual values during the 2012–2015 period. By comparison, water-year precipitation for the Sacramento basin was the third lowest since 1895—highlighting the important role of extreme evaporative demand in 21st century droughts.

Another way to benchmark the ongoing drought is to contextualize water-year precipitation and annual evaporative demand, given their combined influence on drought. Constraining the period of analysis to water years 1980–2021, and focusing on the Sacramento basin, we see a moderate negative correlation suggesting that high-demand years tend to co-occur with low-precipitation cool seasons (Figure 2b). Water year 2021 was unique: it was both the driest water year and had the highest demand for the Sacramento basin of any year in the past four decades. Water year 2020 was close behind—it was the third driest water year and had the third highest demand. Both years were drier and had higher demand than any two consecutive years in the 2012–2015 drought.

Furthermore, while the 1976 and 1977 water years had similar cumulative precipitation deficits to the 2020 and 2021 water years, evaporative demand during the current, ongoing drought is at least 4 inches higher. A hallmark of recent droughts is the acute atmospheric thirst tied to the shifting baselines of temperature and evaporative demand. Increased atmospheric thirst not only depletes soil and vegetated moisture in natural lands, but can also translate into increased irrigation demands for agricultural lands.

Influence of Human-Caused Climate Change

Can we blame this drought on climate change? Not exactly. The predominant driver of droughts in California is shortfalls in precipitation—something inherent to the state's climate. Yet, there is mounting evidence to suggest that climate change has increased evaporative demand and supercharged droughts. The state has warmed nearly 3ºF over the past five decades, consistent with changes simulated by climate models forced by known human activity (i.e., human-caused greenhouse gas emissions).

Changes in precipitation are less clear. There is a non-significant decline in annual precipitation over the past century, yet this decline is entirely due to the past decade that has been punctuated by severe drought. We observe declines in autumn precipitation and a delayed onset of seasonal precipitation that result in a seasonal compression of the wet season. Several generations of climate models agree on one thing regarding changes in precipitation for the state: they agree to disagree. While climate models do not suggest any robust changes in annual precipitation, they show a tendency for less precipitation in the shoulder seasons of spring and autumn and more precipitation in mid-winter.

A few studies have quantified the influence of human-caused climate change on recent extreme droughts in California and the broader southwestern United States. Warming exerts direct control on the mountain snowpack storage efficiency and evaporative demand. The former results in reduced spring snowpack, hastened seasonal drying of soils and vegetation in montane environments, and an advancement in the timing of runoff that further decouples water supply and demand in California's Mediterranean climate. The latter acts as a tax on the surface water balance—like adding a couple of extra straws to a drink. Whereas in wet years, an extra couple of straws sucking surface water may have negligible impacts, the extra straws pulling from the half-empty glasses we experience in dry years intensifies impacts.

Studies estimate that human-caused warming made the 2012–2015 drought in California approximately 8–27% worse. Furthermore, studies show that human-caused climate change has effectively doubled the severity of the "megadrought" that the broader southwestern United States has been in since the turn of the century—turning a significant long-term drought into potentially the worst in at least 1,200 years. Given the elevated evaporative demand in the two most recent years, it is likely that human-caused climate change has its fingerprints on the ongoing drought.

Conclusion

As we end the 2021 water year, the question that we all want to know is when this drought will end. The state may play host to a conga line of drought-busting atmospheric rivers this upcoming winter or may be left high and dry. Improvements in subseasonal-to-seasonal forecasting may help aid in seasonal water-resource decision making. The long-term prospects suggest further increases in evaporative demand with a warming climate that will tilt the odds for acute drought conditions similar to the ongoing drought. This aridification will not be without wet and very wet years. The optimist in me hopes the upcoming water year will be one of these wet years and bring some reprieve to the ongoing drought. The pessimist in me says we should prepare for lean years ahead.

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California Farms Adjust to Drought

Daniel A. Sumner, Carlyn Marsh, Quaid Moore, Scott Somerville, and Josué Medellín-Azuara

During droughts, California farms shift scarce irrigation water to crops with higher payoffs such as vegetables or to orchards and vineyards to maintain asset values. With less forage available from pasture or hay and silage, livestock producers cull herds and shift livestock out of state.

As we learned in the first article of this issue, the 2020–21 drought has been uniquely severe and has affected regions of California differently. Precipitation shortfalls were worse in Northern California and affected livestock pasture areas of the North Coast, as well as the snowpack of the Sierra Nevada mountains. Surface water deliveries were cut drastically, including those for the Russian River basin and some of the most senior water rights holders in the Central Valley. Nonetheless, some important regions, such as the Central Coast, did not have to cut irrigation quite as severely as the Central Valley and the North Coast.

This article reviews farm responses to lack of precipitation and irrigation water supply reductions. We focus on cropping patterns and livestock numbers. The drought is a major focus of California agriculture in 2021, but other vital issues did not fade away when this drought entered the picture. Commodity prices and national and global market conditions, environmental regulations, labor market concerns, continuing pandemic influences, and much more continue to have major impacts on farm prospects in California.

This article uses the best available data and informed judgments to draw the most accurate picture about farm responses to the 2020–21 drought. However, data are not yet fully available, and some farm responses are not yet reported. Therefore, our assessment is necessarily preliminary.

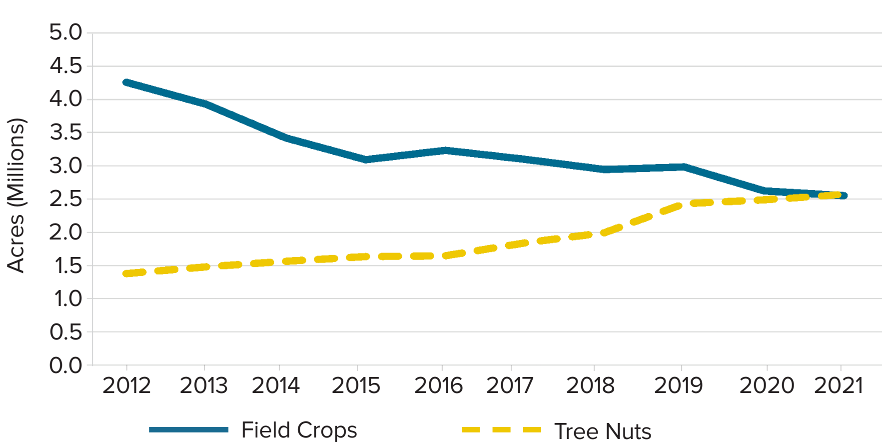
Economic Water Pressures

Crop farms facing increased irrigation water scarcity adjust in several ways, including how much land to plant to which crops and how much land, if any, to leave unplanted. Farms also adjust how much irrigation water to use per acre. Many plans and decisions are based on projected water availability, as well as projected crop prices and costs.

Many farms can adjust spring planting based on considerable, if imperfect, information about water availability (and cost), as well as projections for commodity prices, yields, labor availability, and other input costs. Farms may also consider the opportunity to sell water to willing buyers. At one extreme, farms may leave some fields unplanted, while diverting water to other acreage on the same farm, to other farms, or to non-farm buyers. In some cases, crop insurance provisions pay indemnities for "prevented planting" when below-normal water deliveries are projected. In general, farm managers estimate their expected payoff for each potential water use for each potential water scenario and select options with the greatest net benefit.

Given the need to keep their trees and vines healthy and productive for many years, growers with orchards or vineyards often have less flexibility about their water usage. Nonetheless, in order to economize on water use during a drought, growers may remove some older trees or vines a few years earlier than normal. If growers expect water availability and costs to soon return to normal, these fields may be replanted immediately with young trees or vines, which use little water in the first few years. If water or commodity market uncertainty is severe or delays in access to planting materials prevail, this land may remain unplanted for a season or two. Drought may also occasion a reconsideration of land use, such that some less suitable orchards or vineyards may shift to less water-intensive annual

Figure 1. A Decade of California Field Crop and Tree Nut Acreages



Source: USDA National Agricultural Statistics Service data on "principal crop" (i.e., field crop) and tree nut acreage, with other sources and extrapolations for 2021 non-bearing acres for tree nuts.

crops or be left idle if no profitable options are available.

Rainfed pasture allows little adjustment other than reducing animal stocking rates. With a lack of winter rain or snow, each acre of pasture provides less forage during the spring and summer. Lower stocking density may apply to lower elevation pastures that provide winter forage, as well as to mountain pastures that provide ample summer forage in non-drought years. In the North Coast region of California, organic dairy herds use some of the rainfed pastures that have been hit severely by the 2021 drought. However, most pasture in California serves beef cows with their calves, along with yearling feeder cattle. When there is less pasture forage, calves are weaned early and sold out of state younger than usual, mature cows are culled, and more feeder cattle are shipped out of California.

A Decade of Crop Acreage Patterns

Figure 1 shows the decade-long downward trend in field crops and the accompanying rise in tree nut acreage in California. While these trends have been ongoing for decades, the ten years since 2012 illustrate interesting patterns. In 2012, California had about 4.26 million acres of field crops (the USDA designation of "principal crops") and about 1.38 million acres of tree nuts (almonds, pistachios, and walnuts) for a total of 5.64 million acres. During the 2012–2015 drought, field crop acreage reached a temporary low of about 3.09 million acres in 2015, while tree nut acreage climbed to 1.63 million acres. The combined total was only 4.72 million acres, leaving about 0.9 million acres in other crops or left unplanted in that severe drought. Drought did not seem to affect the steady increase in tree nut acreage but drove a rapid decline in field crop planting.

Between 2015 and 2019, field crop acreage bounced up and down, but ended these four years only 0.11 million acres lower. Meanwhile, tree nut acreage rose by another 0.8 million acres for a total of 2.43 million acres, regaining a combined total of about 5.4 million acres. While field crop acreage held its own, tree nuts captured land that had been left unplanted in 2015, or had been planted to other crops. Finally, in the two years of the current drought, field crops fell to 2.55 million acres and tree nuts rose to 2.57 million acres, now exceeding field crop acreage for the first time. Notice that the combined acreage has fallen again, to about 5.12 million acres, leaving some land left unplanted or available for other crops.

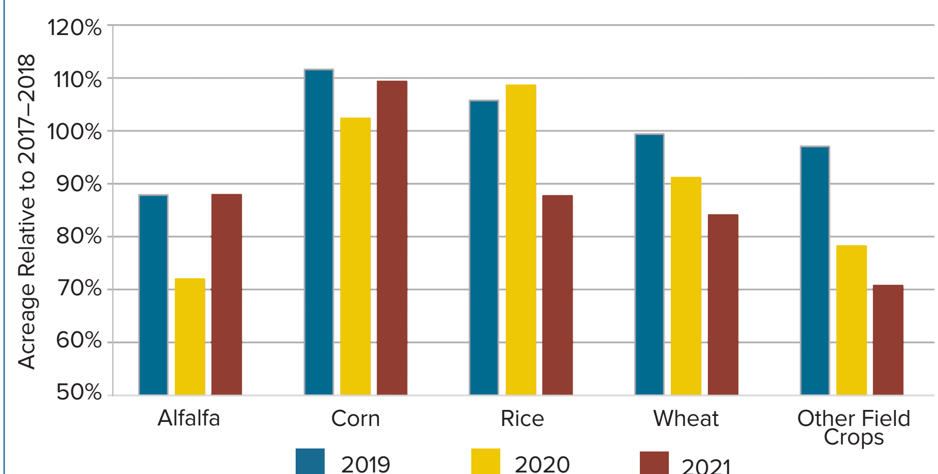
One implication of this shift to more orchards is that California is now less flexible in response to water cuts than it was in 2012 when we entered the previous severe drought. Then, farms had 67% more field crop acreage from which water could shift to keep the trees and vines healthy and the berry, melon, and vegetable crops productive. Now in 2021, the Central Valley alone has about 2.6 million acres of mostly young tree nut orchards and 1.4 million acres of other trees and vines.

Field Crop Acreage Shifts in the Current Drought

Patterns of field crop acreage adjustments in the current drought are displayed in Figure 2. The vertical axis shows acreage relative to the 2017–18 average. The horizontal axis has bars for four important field crops and an aggregate of other field crops. In these USDA data, other field crops include cotton, grains such as sorghum, oilseeds such as safflower, peas, beans, and finally, a few other crops such as sugar beets and potatoes. Compared to 2019, acreage in 2020 was down substantially for all categories of California field crops except rice, which was up slightly in 2020.

For alfalfa hay and corn—most of which is used for silage—the main market is the dairy industry, which is concentrated in the San Joaquin Valley. Alfalfa hay and corn acreage declined precipitously in 2020, only to rise in 2021 back to the acreage of 2019. Alfalfa acreage, already low in 2019, remains at only 88% of its 2017–2018 average. Most grain and protein livestock feeds are shipped in from out of state. In contrast, most forage is produced within the state, because it is expensive to haul. The fluctuating pattern of forage acreage was caused

Figure 2. Acreage of California Field Crops in 2019, 2020, and 2021 Relative to the 2017–18 Average



Source: USDA National Agricultural Statistics Service data on "principal crop" acreage, which includes all field crops but does not include fruits and vegetables.

Table 1. Share of California Field Crop Acres Prevented from Planting, by Crop and Year

	2017	2018	2019	2020	2021
			Percent		
Corn	0.5	0.0	0.1	0.1	0.9
Cotton	3.6	10.6	3.6	26.2	37.4
Rice	19.9	1.4	9.1	6.4	21.0
Wheat	1.1	0.3	0.4	0.4	1.4
All Other Field Crops	0.6	0.4	0.5	0.9	2.1

Source: USDA FSA reported acreages on September 1 for 2017 through 2021.

partly by a pandemic-related collapse in milk prices in the spring of 2020, a subsequent rise in milk prices, and strong demand for forage for the rest of 2020. Milk prices were strong in early 2021, and hay and silage producers have experienced strong market demand, supported by dairy production remaining high in 2021. Even in drought periods, underlying economic forces have major roles in crop acreage patterns.

Field crop acreage in California has fallen substantially from the 2017–2019 average. Declines have been about 20% for rice (100,000 acres), about 15% for wheat (65,000 acres), and about 25% for the other field crops as a group (230,000 acres). Among the other field crops, cotton acreage alone fell by about 160,000 acres to only 110,000 acres in 2021. Overall, field crop acreage fell by about 360,000 acres from 2019 to 2020, and by another 70,000 in 2021.

Cropland Left Unplanted

No data tell us the motivation behind patterns of planted acres, and we have no data on total planted acreage or acreage of most individual crops grown in California in 2021. Nor are there definitive data on cropland left unplanted. We can, however, apply indirect evidence and inference. For example, recall that from 2015 to 2019, tree nut acreage rose faster than field crop acreage declined, indicating that tree nuts were replacing other crops too. But, since 2019, major field crop acreage has declined by 430,000 acres, and tree nut acreage rose by 140,000 acres, leaving a gap of almost 300,000 acres. This huge shortfall suggests that, although some of the land shifting away from field crops may have been planted to vegetables, fruits, or other crops, some of it was likely left unplanted.

One source of information may fill in part of the story. The USDA Farm Service Agency (FSA) requires farms that participate in its major field crop subsidy programs to regularly report how they use all the farmland on that farm. But, most California farmland is not on farms that participate in the covered subsidy programs, so this is only a part of the story. For example, in 2021, the FSA recorded only about 650,000 acres of California tree nuts compared to the more than 2.5 million acres in the state. Thus, the FSA data cannot provide direct information about California land use across its huge variety of crops, but are useful nonetheless.

Crops with large FSA subsidies—such as rice and cotton—have the bulk of their acreage included in the FSA records. Farms report acreage by crop, including acres planted and prevented from being planted. In California, about 85–90% of the "prevented planting" acreage is rice and cotton acreage. California cotton acreage reported to FSA fell from 279,000 acres in 2017 to 136,000 in 2020 and then rose to 170,000 acres in 2021. For cotton, the share of "prevented planting" acreage was about 3.6% in 2019 and about 37% (64,000 acres) in 2021. California rice acreage reported to FSA, including that reported as "prevented," ranged from 481,000 in 2018 to 529,000 in 2019 and was 488,500 in 2021. The amount "prevented" was 105,000 acres (about 20%) in 2017, 7,000 acres (1.4%) in 2018, and 102,000 acres (about 21%) in 2021. Rice acreage reported by FSA as planted in 2021 was 386,000 acres. This number compares to the total 2021 California rice acreage of 415,000 acres reported by the USDA National Agricultural Statistics Service.

Table 1 shows the range of shares reported to FSA as "prevented" for the five years from 2017 through 2021 for four major field crops and the category of all other field crops. Compared to the data in Figure 2, cotton acreage is shown separately and alfalfa is grouped with other field crops. Table 1 shows that the shares of "prevented planting" are very small for corn, wheat, and the category of all other field crops.

A substantial share of rice and cotton is enrolled in USDA-sponsored and subsidized crop insurance programs that pay indemnities for losses attributed to prevented planting claims. One of the approved "cause-of-loss" categories for prevented planting is expected failure of irrigation water supply during the insurance year, such as when local water agencies announce irrigation water delivery plans that are insufficient to produce the crop. The crop insurance indemnity for the prevented planting depends on local conditions during the planting period. Rice and cotton eligibility for "prevented planting" crop insurance indemnities differ year by year, but in a major drought year like 2021, both have high rates of prevented planting.

Satellites provide another source of information on land that is left unplanted. In 2021 satellites have taken multiple measurements that have been calibrated to distinguish between fields that have been planted to crops during the year and fields that have been left unplanted. Preliminary estimates from UC Merced researcher Nicholas Santos suggest a range of between 250,000 and 750,000 acres of land left unplanted in California's Central Valley in 2021. The large range reflects the uncertainty inherent in the careful interpretation of the satellite data.

The Sacramento Valley has about one-third of the projected unplanted cropland and the San Joaquin Valley has the other two-thirds. Unlike past droughts, the Sacramento Valley was unusually dry this year, and water districts there have curtailed deliveries much more severely than in past droughts. This is consistent with the satellite evidence of much more land left unplanted north of the Delta. The location of satellite-estimated unplanted land overlays fields that typically grow rice, other grains, and similar field crops; thus, these projections are consistent with the patterns seen in the prior drought years.

Drought Impacts on Pastures and Cattle Numbers

Much grazing land in California is used seasonally. Livestock, especially cattle, are placed on mountain pastures during the late spring through early fall and moved to valley and foothill pastures for the rest of the year. During 2021, precipitation on pastureland was low and, with less forage available, livestock producers adjusted grazing patterns. At the same time, hay production was reduced in California and other Western states, so forage feeds were more expensive. With less pasture forage available, operators reduced the number of livestock on pastures in California. We do not yet have the aggregate data to quantify this reduction.

Data on grazing livestock numbers are available by state in January of each year. On January 1, 2021, California had about 670,000 head of beef cows, the same as in 2018, but up almost 15% from the depths of the last drought in 2015. We will learn how the current drought has affected the size of the cow herd when the January 1, 2022 numbers are released.

An interim and partial assessment of the effects of the drought on cattle numbers may be gained from considering beef cow slaughter data, which are available monthly by region. Beef cow slaughter for April through July of 2021 in the Southwest region (of which California makes up 57%) was up by about 32% above the average of the previous three years. This represents an excess slaughter of about 2.2% of the regional cow herd. The slaughter rate was especially high in July and August compared to prior years. We note, however, that some other regions in the United States experienced equally large increases in cow slaughter over the same period, so we cannot definitively attribute the increased slaughter in our region to drought. Moreover, even if the excess slaughter is drought related, it amounts to around 2% of the cows, which is far from wholesale herd liquidation.

Finally, we note that the California dairy industry has continued to have relatively high quantities of milk production throughout the drought. With the exception of the 2% of production that is organic, California milk cows do not use pasture. Except for alfalfa and silage, most of the feed is either by-products, such as almond hulls, or shipped into California from other states. So far, California milk production has not fallen.

Conclusions

This article summarizes the direct responses of California crop and livestock producers to the current 2020–21 drought. Crop acreage has adjusted, and water has been reallocated to crops for which the payoff is highest. Some land has been left unplanted, and for some, crop insurance indemnity has been available. With less forage in California pastures, more beef cows have been culled, and there are reports of cattle being shipped to pastures out of state.

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Authors' Bios

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Drought Impacts on California Farm Revenue and Prices

Daniel A. Sumner, Elizabeth A. Fraysse, Scott Somerville, and Josué Medellín-Azuara

Droughts in California reduce the availability of irrigation water, raise costs, and have dire consequences for some farms. However, as with earlier droughts, the 2020–2021 drought is having only small impacts on farm revenues and prices. Farm responses to drought generally minimize the drought's overall impacts and protect consumers from severe food price increases.

Fresh produce grown in coastal regions, like leafy greens, are less prone to irrigation cutbacks during a drought.
Photo credit: iStock

The drought of 2020–2021 has been particularly severe; precipitation was low and irrigation water deliveries were cut drastically. The previous article documented that the farms in California made many adjustments when faced with reduced water quantities, more expensive irrigation water, and other consequences of drought.

This article describes relatively small overall price and revenue consequences for California crop and livestock farms and ranches and small effects on consumers from this drought. California agriculture is large (about $50 billion in sales) and diverse (hundreds of commodities). Farms have made many adjustments to mitigate drought impacts, and this drought has occurred during a period of otherwise strong revenue prospects.

Overall, we expect that revenue this year will increase, although it is unlikely to reach the record-high farm revenues reached in 2014, which was also a dry year. Farm costs are also high this year; therefore, net revenue is likely to be moderate at best.

Drought and California Prices and Farm Revenue

There are several reasons that drought has not generally caused substantial variation in California farm revenue. First, droughts have generally had relatively small effects on the output of coastal agriculture, which comprises about 25% of farm output and includes major vegetable, berry, winegrape, and greenhouse and nursery industries. Second, during droughts, California farms pump more groundwater and shift available irrigation water to high-revenue crops, which tends to maintain aggregate revenue.

Third, for some field crops such as rice, alfalfa hay, and corn silage—from which acreage and irrigation water is shifted during a drought—farm prices tend to rise to partly offset the reduction in output. Fourth, for milk, beef, poultry, and egg output (about 25% of California farm revenue) revenue generally responds indirectly and may rise or fall. Finally, revenue variation is driven largely by subtle non-drought weather variations affecting yields and national and world price variations that are not influenced much by California conditions.

Several of these factors also influence why consumer prices do not respond much to California drought. Many of the crops, such as many fresh produce items, for which California is the main or only supplier to the national market during certain seasons, are grown in coastal regions that are less prone to irrigation water cutbacks during a drought. Other crops, such as tree and vine crops, have water shifted to them to maintain production during drought because they are the crops with higher revenue per unit of water.

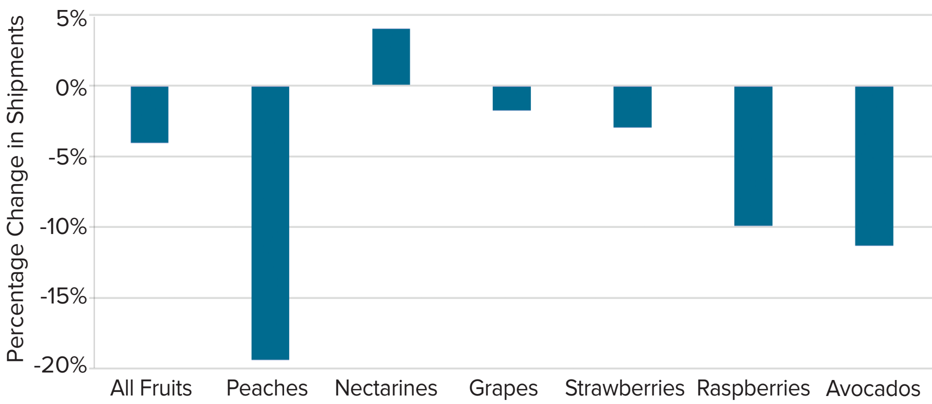
Crops that are subject to supply reductions, such as some grains and other field crops, tend to be those crops for which California supplies a relatively small share of the market. Hence, they have their prices determined by supplies outside of California. As we see below, rice, melons, and processing tomatoes are a partial exception to this rule. Finally, some crops that experience reduced production during a drought, such as corn silage and alfalfa hay, are fed to livestock, not people, and thus their impacts on consumer prices are indirect and diluted.

Observed Impacts of the 2020–21 Drought on Farm Prices and Revenues

Let us now review available data to assess potential drought effects. This is difficult in part because commodity markets have lots of normal variability in production and prices from year to year, even without drought impacts. Moreover, the drought began in 2020 and has overlapped with the pandemic.

This section provides market price and quantity assessments for several important crop categories. But first, we should note that production and price movements for some California commodities are only remotely connected to drought. For example, nursery and flower products (worth about $4 billion) are often grown in

Figure 1. Percentage Change of California Fruit Shipments, 2021 Compared to the 2018–2020 Average*



*Note: All-fruits percentage change is a quantity weighted average and includes blackberries.
Source: USDA Agricultural Marketing Service Custom Reports for 2018, 2019, 2020, and 2021.

controlled environments and generally use small amounts of water per dollar of output, compared to other crops. Citrus crops (worth about $2 billion) are grown both on the South and Central Coast and in the Central Valley, but they are a winter-harvested crop and one for which we do not have data for this harvest year yet. On the livestock product side, poultry and eggs (worth more than $2 billion) are fed mostly grains and oilseeds that are shipped into California.

Fresh Produce

To assess produce quantities that may have been influenced by drought, we compare weekly USDA Agricultural Marketing Service data for 2021 with the prior three years. In particular, we consider berries, grapes, tree fruits, lettuces, and other major fresh vegetables. Of course, produce shipments vary from year to year for many reasons, so we do not make definitive claims about differences in shipments caused by drought.

Fresh fruit and vegetable shipments in 2021 are a bit lower compared to the three prior years. Fruit shipments are down about 4% in 2021 (Figure 1). Among Central Valley fruits, which are more likely to be affected by water cuts, peach shipments were down by 19%, but nectarines shipments were up by 4%. Grape shipments—a large share of the total—were down less than 2%. Among coastal fruits, avocados were down 11%, but this decline is unlikely to be drought-related. Blackberries rose by about 50% from a small base, but strawberry shipments, which account for most of the coastal fruit shipments, were down just 3%. Vegetable shipments—for which most production is in coastal counties—fell by only 3%. The big drop in shipments was in melons (down 34%), which as annual crops grown in the Central Valley, are sensitive to irrigation water cuts.

Tree Nuts

Tree nuts account for about 20% of California farm revenue. As shown in the second article, the production of California almonds, pistachios, and walnuts has more than doubled in the recent decade and is on track to continue to expand, as recently planted orchards come into production. The alternate-bearing tendency of these crops makes simple year-to-year comparisons complicated.

After high yields per acre last year, the 2021 yields for almonds, and especially pistachios, would likely have been low in 2021, even without the drought. Nonetheless, the recently harvested 2021 crop is likely smaller than it would have otherwise been because some acreage of mature trees was removed and because yields were reduced by irrigation cutbacks. Low production will boost prices somewhat from what would have prevailed because California has a large share of world production for these crops. However, annual carryovers moderate price hikes caused by lower than expected yields.

Unless tree nut demands, and therefore prices, are unusually strong over the next several months, revenue from the 2021 crop, which is mostly realized in 2022, will be down. Since much of the tree nut revenue realized in 2021 is from sales of the 2020 crop, we may see a rise in 2021 annual revenue.

Rice, Cotton, and Other Grain Crops

As noted above, California grain, oilseed, and cotton prices are determined largely in national and international markets. Prices for grain, such as corn and wheat, have risen by 30% or more in 2021 relative to prior years. The increase is not because of reduced output in California, which is a very small share of the relevant market, but mainly because of low stocks and increases in international market demands. Likewise, cotton prices are about 40% higher in 2021 than in recent years. Although California acreages and production are down substantially, California revenue for these crops may actually be higher in 2021 due to high market prices unrelated to our drought.

California grows japonica rice, which has a market price that moves separately from, and is much higher than, the price of rice from other states. The distinct demand for California rice means that when the quantity of California rice falls, the price of California rice rises. In 2021, the quantity of California rice will likely be down by about 25%, and the price is projected by USDA to rise by about 10% above the average of the prior two years.

Table 1. Differences in Average April–August Prices in 2021 Versus 2017–2019

Commodity	Percentage Change
Fed Cattle	-2%
Feeder Cattle	2%
Milk	12%
Alfalfa Hay	7%
Corn Silage	42%

Note: Prices for alfalfa, silage, and milk are for California. Prices for feeder cattle are for the Western states, and for the Midwest for fed cattle.

Source: Silage prices are from the Hoyt Report. Cattle, hay, and milk data are from USDA.

California rice revenue is likely to fall by about 11%, or about $100 million. Given the added costs as rice moves from farm to consumers, retail prices are likely to rise by less than 5%, and the additional cost of a meal at your local Korean restaurant, which probably uses California rice, will be too small to notice.

Beef and Dairy and Forage Crops

Sales of cattle and calves from California have been about $3 billion in recent years. Cattle and calves rank fourth among California commodities, but still comprise only 5% of the U.S. total. The California shares of both the fed cattle segment (steers and heifers that have been fed intensively) and the cow-calf and feeder cattle segment (the cattle on pasture used for breeding or not yet ready to enter the feedlots for intensive feeding) are too small to have much influence on national cattle prices. For 2021, fed cattle prices are up compared to last year's pandemic-lowered prices, but down 2% from the average of 2017–2019 (Table 1). Western feeder cattle prices in 2021 are 2% higher than the 2017–2019 period. Cattle gross revenue (not net revenue) is likely to be up slightly in 2021 because of drought-induced pressure to sell more cull cows and feeder cattle.

California has farm sales of milk of about $7 billion. Year-to-year variation in milk revenue has large effects on aggregate farm revenue in California. Milk revenue will likely be up in 2021 because production will be up by a few percent; the average price of milk will be higher than in 2020 and up by 12% over the 2017–2019 average. However, government payments to dairy farms are lower in 2021 than in 2020.

The dairy industry is the major source of demand for hay and silage from California farms. The second article explained that strong demand from dairy farms caused hay and silage acreage to rise in 2021 compared to 2020, back to the average of 2018–2019. Alfalfa hay production is up by 10% from last year, but down from 2018 and 2019; alfalfa hay prices are up 7%, so revenue is up significantly from the 2017–19 average. Corn for silage production is also up in 2021, with prices up about 42% compared to the 2017–19 average revenue, and cost to dairy farms is up substantially.

Final Remarks

A main thrust of this article is that, while drought has major impacts on California crop and livestock farms, the overall impacts on aggregate farm revenue during drought years are likely to be small. California farm revenue hit new highs during the nadir of the 2012–2015 drought, and farm revenue will likely remain relatively robust in 2021 as well.

Also, as in previous droughts, this California drought has had only small effects on consumer food prices. The California farm price impacts that would most influence food costs—the price of fresh produce crops, for which California supplies a large share of national consumption—tend to be small. These produce crops tend to be grown mostly in the less drought-affected regions, and they have among the highest returns per unit of irrigation water. Thus, farms shift water away from other crops to maintain fresh fruit and vegetable shipments. In addition, the marketing margins from farm to consumer are usually the largest share of the consumer price, and therefore, a drought-induced increase in the farm price has a diluted impact on the percentage change in consumer prices.

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Identifying Policies to Mitigate the Costs of Drought

Ellen M. Bruno

In this article, I discuss past and current strategies to mitigate the costs of drought. Adapting to future droughts will require policy changes that increase the flexibility in use of both surface water and groundwater, particularly from year to year.

Crises often lead to policy change, and drought is no exception. The last drought spurred the Sustainable Groundwater Management Act (SGMA) of 2014, which is revolutionizing the way groundwater is managed throughout California and providing incentives to store water underground during wet years for use during dry years.

Previous droughts have resulted in similar policy changes. For example, the 1991–1992 drought begot the passage of the Central Valley Project Improvement Act (CVPIA) and the development of the Kern County water banks, both major water policy advances. Each policy advance has provided an opportunity for market-based instruments to emerge or advance. The CVPIA increased the ability to transfer water between users across space and the water banks enabled water transfers within users over time.

Although large variability in precipitation from year to year is normal for California, we face a future where climate change may exacerbate droughts. As we grapple with drought this year and in the years to come, it will be important to continue to reevaluate the strategies at our disposal for mitigating the costs of drought.

What policies are needed so that we can better adapt to periods of water scarcity? In this article, I discuss past strategies for mitigating the costs of drought and their potential, the current challenges in groundwater management, and potential future policies to improve water allocation in the state and reduce the costs of drought in years to come.

Groundwater Supplies

Historically, groundwater has served as an adaptation strategy during times of drought to buffer costs associated with reduced surface water supplies. But under open-access conditions, where groundwater pumpers face little to no constraints on well drilling or pumping, groundwater levels get drawn down increasingly over time, increasing the costs for everyone to access that groundwater. Groundwater in California is largely unmetered and property rights to groundwater are not well defined.

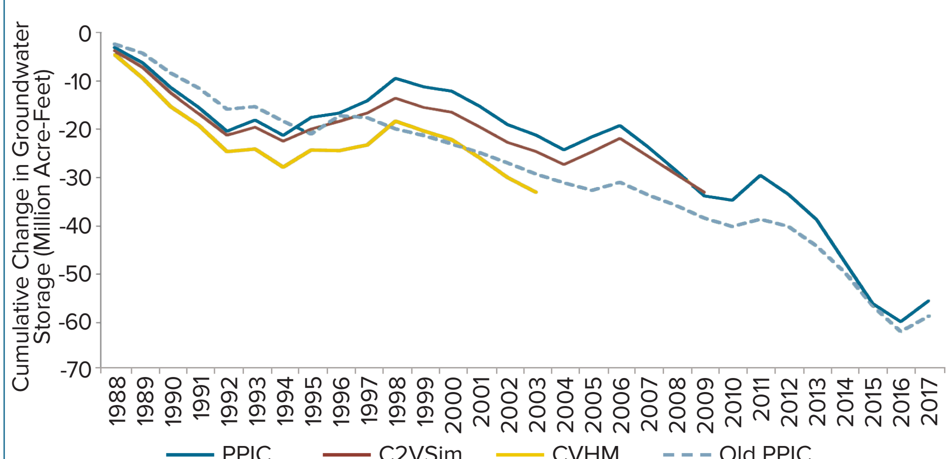
Since groundwater pumping is largely unmetered, hydrologic models have difficulty estimating groundwater balances without much ground-truth data. Figure 1 shows that while there are differences across models, there is general agreement on the decline in San Joaquin Valley water storage over time. The lowering of groundwater levels implies higher costs to pump, decreasing the buffer value of groundwater during droughts. If left unaddressed, the buffer value of groundwater will decrease over time as this resource becomes increasingly inaccessible and expensive.

California's Surface Water Market

The surface water market has also been seen as a strategy to mitigate the costs of drought. Farmers in California can voluntarily reallocate scarce water supplies amongst each other using a vast network of infrastructure, subject to regulatory constraints. If scarce water can be reallocated to its highest-valued uses, then the largest costs of drought can be avoided.

However, California's surface water market is characterized by low transaction volume and that volume has remained low since the early 2000s. On average, California uses about 43

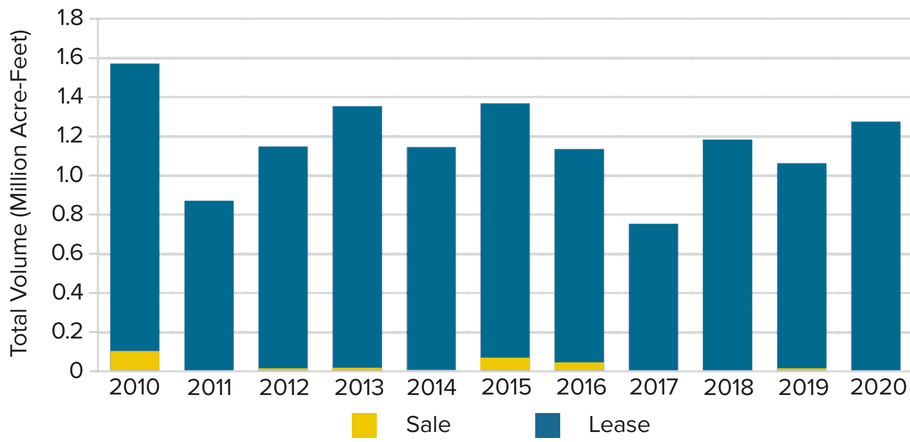
Figure 1. Cumulative Change in Groundwater Storage in the San Joaquin Valley



Note: Lines represent estimates of the cumulative change in groundwater storage from different models.

Source: Adapted from the Public Policy Institute of California's (PPIC) report "Water and the Future of the San Joaquin Valley. Technical Appendix A: Updated Assessment of the San Joaquin Valley's Water Balance." Available at: https://bit.ly/3Bcye9N.

Figure 2. Total Volume of Water Transacted in California's Surface Water Market



Source: "The Future of Water Markets: Obstacles and Opportunities." Clay Laundry presentation, July 20, 2021.

million acre-feet (AF) of water each year for agricultural and urban uses, with 80% of that (34 million AF) going to irrigate crops and the remaining 20% (8.6 million AF) going towards residential, commercial, and industrial uses. Meanwhile, total volumes traded in the surface water market haven't exceeded 1.6 million AF in the last 10 years, and these include transfers to and from urban areas.

Figure 2 plots the volume of water traded in California since 2010. Volumes in any one year range from 700,000 AF to 1.6 million AF and look small compared to the total water use in the state, averaging just 4% of statewide use.

Perhaps a better comparison point than statewide water use is the quantity of surface water deliveries in an average year, since groundwater is known to constitute 40% of the water supply, on average. California Department of Water Resources data from 1998–2015 shows that during drought years in that period (2007–2009 and 2012–2015), water supplied from state, federal, and local projects, plus the Colorado river, averaged 19.7 million AF. By contrast, it averaged 24.9 million AF during the remaining non-drought years (1998–2007 and 2009–2012). Comparing deliveries in drought years to non-drought years throughout this period of 17 years, we see that the average drought-induced deficit in surface water deliveries is around 5.2 million AF.

This implies that quantities traded in the surface water market make up for a non-trivial amount of the average drought-year deficit in surface water deliveries. However, the volume of water traded in the surface water market has remained constant since the early 2000s. If water scarcity increases and the market size remains unchanged, then its capacity to mitigate the costs of drought in the future may be limited.

The Sustainable Groundwater Management Act (SGMA)

Presently, the state is grappling with new groundwater legislation. SGMA requires newly formed groundwater management agencies to develop and implement plans to achieve groundwater sustainability over the next 20 years.

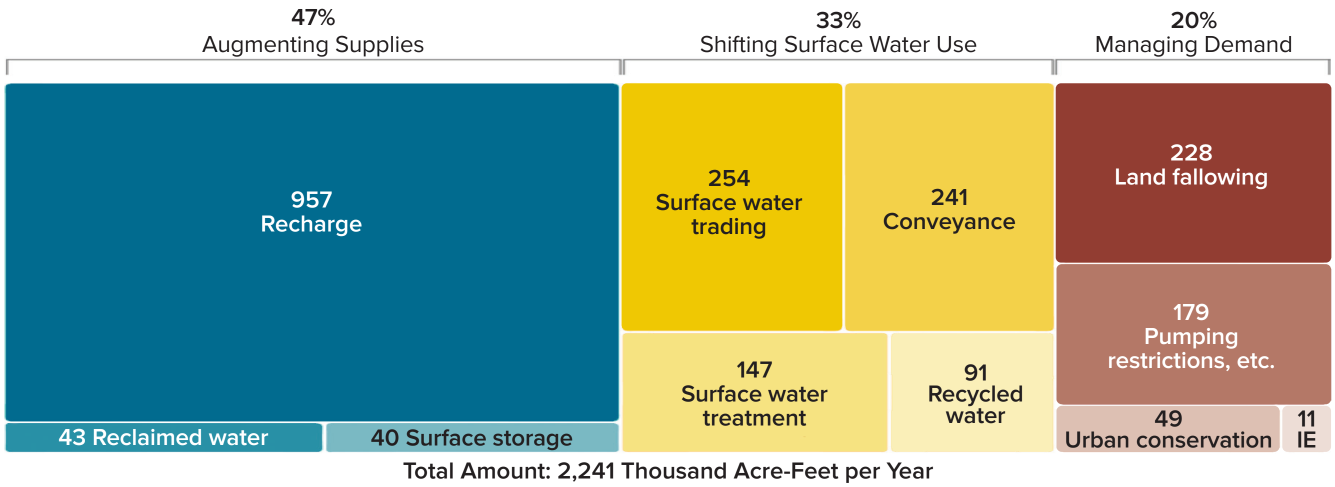
Maintaining groundwater storage seems broadly good for long-run adaptation to droughts and climate change. However, agricultural users may be concerned that measures taken to maintain groundwater levels in the short run could hinder their ability to make up for shortages in surface water during times of need. For example, if agencies restrict groundwater pumping in order to let groundwater levels recover, this may further exacerbate the costs of drought for growers.

In reality, it looks like SGMA is acting primarily as an incentive for agencies and users to recharge the groundwater through increasing supply, as opposed to reducing demand. Figure 3 summarizes how groundwater agencies plan to bring their basins into balance, with almost 80% of the overdraft deficits being met with either supply augmentation strategies, like artificial groundwater recharge using winter flood flows, or with shifting surface water use, like recycled water. If climate change condenses the winter period in which the bulk of precipitation falls and reduces the snowpack storage capacity by shifting the form of precipitation from snow to rain, then it is good that local water managers and state regulators are taking action to use our groundwater aquifers as underground storage.

Most groundwater plans reveal that agencies are using groundwater cutbacks as a last resort to achieve sustainability. Although they will likely be necessary for some of the most overdrafted basins, groundwater agencies are largely incentivized to find other solutions. Many of the agencies that are considering groundwater restrictions or allocation, are also considering the development of a groundwater market to trade those allocations.

Of the proposed groundwater management plans that have been submitted so far, 60% suggest the possibility of setting allocations, and two-thirds of those say they will consider facilitating the trade of those allocations. Allowing trade of allocations is an important part of reducing the economic cost of pumping restrictions.

Figure 3. Summary of Groundwater Management Plans Under SGMA



Note: The amounts are shown in thousand acre-feet per year. IE is irrigation efficiency. The pumping restrictions category also includes groundwater allocations, water metering, pricing incentives, and groundwater trading. Reclaimed water includes desalinated brackish groundwater and water produced by oil extraction.

Source: PPIC Report: "A Review of Groundwater Sustainability Plans in the San Joaquin Valley." Available at: https://bit.ly/3mdmL3A.

Coping with Future Droughts

Mitigating the costs of future droughts will require a suite of policy instruments. There is no silver bullet for fixing California's water problems, but there is potential for improvement in many areas.

Efforts to allocate water more efficiently, both across space and over time, will enhance the value derived from scarce water. Water is unlike other commodities in the way we can and cannot move it around and in the way moving it around can harm the environment and communities. Market-based policy instruments need to be designed with these issues in mind.

Spatial arbitrage of surface water is limited because of physical transport constraints and regulations that are designed to protect third parties from harm. Reducing the transaction costs of surface water trades, while ensuring protections—e.g., by streamlining the approval process or centralizing information—could increase the adaptive capacity of the surface water market. Estimates by Nick Hagerty suggest that eliminating transaction costs in the wholesale market for surface water could lead to benefits ranging from $86 to $278 million per year. Simultaneously enabling trade of either surface or groundwater at the local level—within irrigation districts and between agricultural and urban users—would lead to further gains.

Policies to improve arbitrage across time could also greatly enhance the ability of users to adapt to water scarcity. The Sierra snowpack, combined with our system of surface water reservoirs, enables us to capture and store water during the winter for use during the summer. This system does a remarkable job of reallocating use over time within a year. However, we could do more to store water from year to year and enable water users to arbitrage across longer time horizons.

While SGMA is encouraging agencies to bank excess water during wet years, efforts to set up more official groundwater banks—where formal accounting systems enable individual water users to draw from their reserves when needed—will enhance the flexibility of water users. The Kern County water banks remain the most active groundwater banks in the state by far; other regions could take advantage of a similar scheme.

It's largely accepted that there isn't much capacity left for additional surface water storage. All the most promising areas for dam construction have already been built. However, we have vast storage potential underground. We need to take advantage of this, while creating mechanisms for water users to flexibly arbitrage across both space and time. This can all be done with protections to reduce harm to third parties.

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