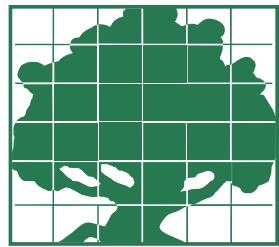


Agricultural and Resource Economics UPDATE

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Special Issue: The Economics of the Drought for California Food and Agriculture

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The extreme drought that has gripped California over the past several years is causing onerous adjustments in the natural and human environments. Agriculture, which uses much of the state's water, is at the center of many of these arduous responses. The 2015 impacts of the continuing drought are still underway, but in this special *ARE Update* issue, we project responses and consequences within agriculture and more broadly.

In this issue, Hanak and Mount put this drought in the context of California's history and put agriculture in the context of water institutions, management, and distribution throughout the state. Next, Medellin-Azuara and co-authors develop detailed, and albeit preliminary, assessments of 2015 irrigation water distribution. They estimate a cut to agriculture of about 8.8 million acre-feet, or about 30% of what might be available in a normal year. (This number may be an underestimate given recent events.) During droughts, farms increase groundwater pumping. The authors estimate that farmers and ranchers will replace about 6.2 million acre-feet of lost surface water deliveries with costly increases in groundwater pumping, where possible in 2015.

Another painful response to drought is to leave land idle. The authors estimate about 564,000 more acres, mostly

field crop land in the Central Valley (including irrigated pastures), will be idled in 2015. This too may be an underestimate. USDA reported on June 30, that 2015 California acreage of "principal crops," (defined as field crops such as hay, grains, oilseeds, cotton and potatoes) is about 900,000 acres below the 2013 total of about four million acres. Over this period, tree nut and tomato acreage increased by about 180,000 acres. So, even accounting for the steady shift to tree nuts and some other higher revenue per acre (and per acre-foot) crops, there is a strong indication of severely accelerated reductions in field crop acreage in California.

The economic toll of the drought is fewer jobs and smaller value of output and economic contribution that would have otherwise occurred. Based on 564,000 idled acres, Howitt et al. estimates farm revenue losses of \$1.8 billion, economy-wide revenue losses of \$2.7 billion, and 18,600 fewer jobs due to the agricultural drought.

That these economic impacts are not even larger is a testament to the extraordinary efforts and innovations by farmers, and others in California agriculture. Idling land, shifting water across crops, and using each acre-foot more economically all have led to smaller losses of revenue and jobs, and only very small price increases for consumers.

Putting California's Latest Drought in Context

Ellen Hanak and Jeffrey Mount

California's latest drought has focused attention on water management practices and policies. This article describes how the system has adapted to managing water scarcity and recurring droughts. It identifies some of the early lessons learned, including promising ways to adapt to water scarcity and areas of continued vulnerability.

California remains in the grip of a major drought. Four consecutive years of below average to critically dry conditions have affected all aspects of water use in the state, with agriculture and the environment hit the hardest. The drought has also brought considerable attention to water management practices and policies, with abundant calls for reforms and for the construction of new water supply infrastructure.

Droughts, like any other natural disaster, can be a catalyst for change, and this drought has been no exception. In 2014 the California Legislature passed the most comprehensive groundwater legislation in state history—the Sustainable Groundwater Management Act. In that same year, the voters passed a new bond bill that provides \$7.5 billion for expanding water supplies, promoting conservation, and improving ecosystems. And the Governor has issued several emergency declarations that contain unprecedented requirements for water conservation in the urban sector. As this drought continues, there will likely be many new proposals.

This article provides an overview of California's water management and use and the way the system has adapted to

managing water scarcity and recurring droughts. In addition, we describe the characteristics of this latest drought and identify some of the early lessons learned, pointing both to promising ways to adapt to water scarcity and to areas of continued vulnerability.

California's Water in Context

California's water supply infrastructure and system of water laws and rights reflect decades of adaptation to a unique climate. Though rarely appreciated during a drought, California is actually a water-rich state, receiving a statewide average of more than 200

million acre-feet of precipitation annually. Roughly two-thirds of that water returns to the atmosphere through evaporation and transpiration by plants and trees, with the remaining flowing down rivers and into aquifers.

However, this abundant water is not distributed equally in space or time. Almost three-quarters of the precipitation that falls on California occurs north of Sacramento, while three-quarters of water use is to the south, with the highest uses in dry agricultural regions of the San Joaquin Valley and Tulare Basin. California also has the distinction of

Figure 1. An Extensive Conveyance and Storage Network



Source: California Department of Water Resources

having the most variable climate in North America, with dramatic year-to-year variations in precipitation.

To adapt to this variable climate, in the mid-20th century, Californians developed one of the world's most vast, complex networks of water storage and conveyance facilities (Figure 1). More than 1,400 surface reservoirs have the capacity to store more than 40 million acre-feet of water—approximately equal to the average annual water use by cities and farms. In addition, more than 500 groundwater basins store at least three times that amount.

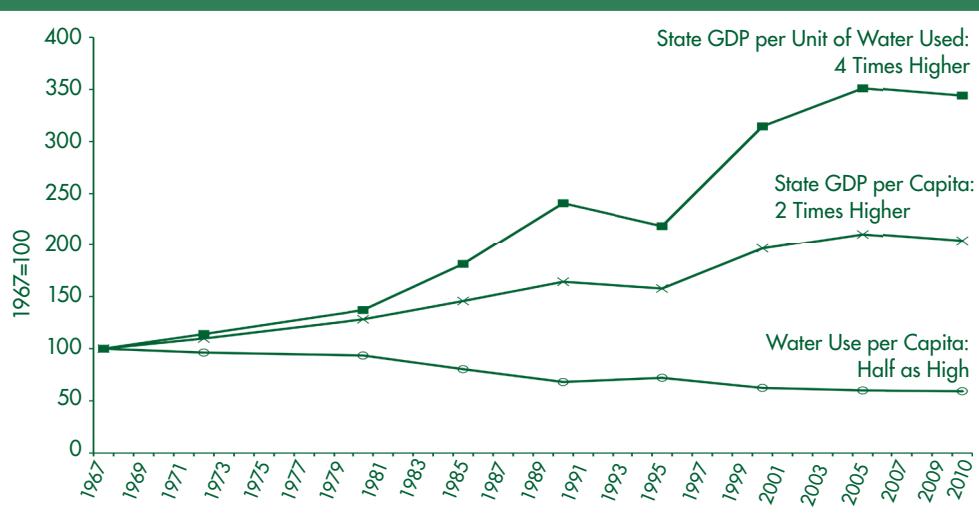
Snowpack—principally in the Sierra Nevada—typically provides temporary seasonal storage of as much as a third of the water used annually. Thousands of miles of aqueducts move water from the northernmost watersheds of the state to farming centers in the Central Valley, and San Francisco Bay Area, and Southern California urban centers. The state also augments supply by diverting more than a quarter of the annual runoff of the Colorado River, supplying farms in the Imperial Valley and urban uses in Southern California.

Who Uses How Much?

Water use in California—as accounted for by the California Department of Water Resources—is concentrated in the environmental and agricultural sectors. Roughly 40% of water use is assigned to agriculture, 50% is assigned to the environment, with the remaining 10% for urban uses. (These figures are for the period 1998–2010, the last year for which statewide water use estimates are available; this is the same source used to produce the other commonly cited breakdown for water directly used by people: 80% by farms and 20% by cities.)

Urban and agricultural water use is governed by the state's seniority-based water-rights system, established soon after statehood. As in other western states, priority of use generally goes

Figure 2. Some Key Water and Economy Trends



Source: Ellen Hanak et al., 2012. "Water and the California Economy," PPIC, updated to 2010 with data from the Department of Water Resources, the Department of Finance, and the U.S. Bureau of Economic Analysis.

Notes: State GDP (gross domestic product) is adjusted for inflation.
Water use estimates are for applied use in the agricultural and urban sectors.

to those who claimed the right first. (In California, those with property directly adjacent to rivers have a special type of seniority known as a riparian right, a type of right more commonly found in the wetter, eastern U.S.)

The seniority-based water rights system is one of the many adaptations the state has made to manage its variable climate. When there is insufficient water to meet all water rights, the State Water Resources Control Board curtails diversions by those with more junior water rights. During the current drought, the Board has found it necessary to curtail water rights established as far back as 1903 and may well go back even further before this summer is over.

In contrast to common understanding, most environmental water is not in direct competition with human uses. For example, most water in Wild and Scenic Rivers—which accounts for over half of environmental water—flows down North Coast rivers where there are no alternative uses. And a large share of required outflow from the Sacramento-San Joaquin Delta—another category counted as environmental water—is needed to maintain

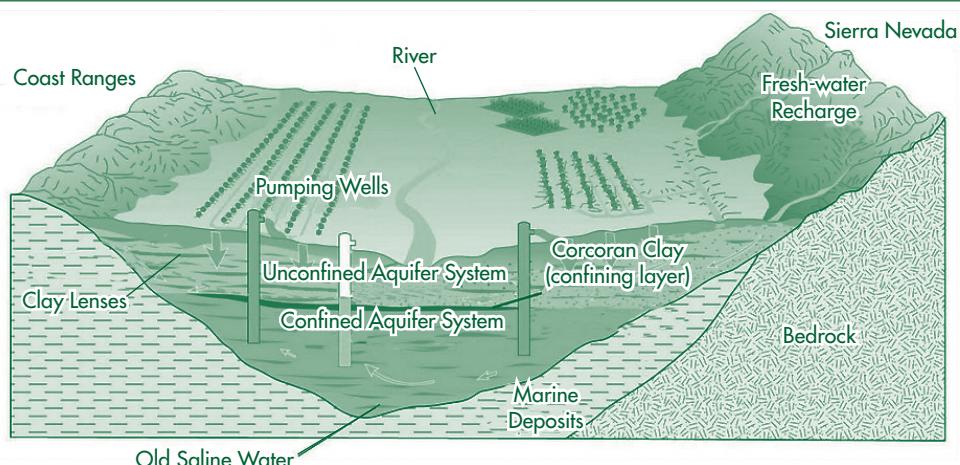
salinity standards for agricultural and urban water uses. However, regulatory decisions in some watersheds have resulted in supply reductions for farms and cities in recent years; San Joaquin Valley farmers dependent on water shipped through the delta are among those affected.

A History of Adapting to Water Scarcity

Since the early 1970's, the state has added nearly 20 million people to its population. During this time, there has been only limited expansion in water supply infrastructure, and yet the state's economy has continued to grow. From 1967–2005, statewide per capita water use declined by half, real state GDP doubled, and the economic value of each unit of water increased fourfold (Figure 2). These trends—temporarily slowed by the recent recession—reflect increased efficiency of water use in all sectors.

Although agricultural water use likely peaked in the early 1980s, productivity growth and shifts toward higher-value activities have spurred continued increases in the economic value of crop and livestock

Figure 3. Schematic of Groundwater in the Central Valley



Source: U.S. Geological Service

production, which now generate over \$22 billion in GDP and over \$48 billion in revenues (2012\$)—roughly double the size in the late 1960s.

Urban use (including all residential, commercial, and industrial water) plateaued later, once utilities began to significantly promote water use efficiency in the 1990s. Daily per capita urban use fell from a peak of 247 gallons in 1995 to 199 gallons in 2010, enabling California to accommodate continued population growth without expanding total urban supply.

What Makes This Drought Unique?

The latest drought, which began in 2012, is not without precedent. Climate scientists have noted that the aggregate amounts of precipitation fall within the range of normal variability. Rather, the drought's hallmark has been its warmth. Statewide and regional temperatures have dramatically exceeded historic highs going back to the late 1800's. Warm temperatures increase the length of the growing season while also reducing soil moisture due to evaporation.

Unusually warm temperatures during the winter led to a higher proportion of rain to snow, resulting in record low snowpacks in 2015. Water stored in both the soil and snow is critical to managing water demand in

California and to the health of river and stream ecosystems. These losses amplified the effects of low amounts of precipitation.

The consecutive dry years, coupled with unusual warmth, led to reductions in available surface water, with dramatic declines in year-to-year storage in the state's large reservoir systems. As outlined in the companion articles in this issue, these shortages hit the agricultural sector particularly, requiring extensive use of groundwater and fallowing of land.

Drought Adaptation Using Portfolio Approaches

California's cities—and particularly the large metropolitan areas—have weathered the drought better than the agricultural sector. This stems in part from some key lessons learned during a major drought from 1987 to 1992, when urban areas were hit very hard.

Following that drought, cities made major investments in portfolio approaches to water. In addition to increasing water use efficiency through new technology and improved pricing approaches, urban utilities diversified their supplies. This included development of nontraditional sources like recycled wastewater, new local surface and groundwater storage, new interties for emergency water sharing among

local agencies, and long-term water purchase agreements from some farmers.

In this drought, attention has focused on bringing down outdoor water use, which still accounts for roughly half of total urban use (and more in hotter, inland areas)—thanks in part to the continued prevalence of thirsty, cool-season turf grass in urban landscapes.

Farming in California is inherently more vulnerable to droughts because it requires large volumes of water for irrigation, and some portfolio tools are less effective in the farm sector. Improving irrigation efficiency stretches on-farm supplies and enhances crop productivity, but it generally does not create basin-wide water savings because it does not lower net crop water use. (Indeed, more efficient irrigation technology often increases net water use per acre by facilitating productivity gains.)

New storage is also a more limited option for farmers. Although some have invested in relatively economical groundwater storage, agriculture cannot generally support the cost of new surface storage. However, the growth of a statewide water market since the early 1990s has significantly improved agriculture's adaptation capacity. The market enables farmers growing higher-revenue crops to purchase water from those with more reliable supplies and lower-revenue cropping opportunities. During this drought, water trading has made it possible to keep orchards alive in some areas that would otherwise have received little or no water deliveries.

Remaining Hurdles

Although improvements in the economic efficiency of water use and diversification of supply portfolios have helped limit the impact of periodic droughts and growing water scarcity in California, several issues remain to be addressed.

Groundwater Management

Groundwater is still California's best hedge against drought. But since the 1960's, California's water supply has been augmented by approximately two million acre-feet per year by groundwater overdraft. This has greatly diminished the utility of groundwater as a drought supply. Figure 3 shows the structure of the groundwater basin in the Central Valley.

As the companion article by Medellín-Azuara and others points out, in 2014 and 2015, farmers will have pumped at least 11 million acre-feet of additional groundwater to make up for lost surface supplies, with prospects for much more if the drought continues. Although the 2014 Sustainable Groundwater Management Act requires that groundwater basins be brought into balance, the reform will be phased in over 25 years. To address growing water scarcity in the agricultural sector, early adoption and accelerated implementation will be beneficial.

The Delta Conundrum

The Sacramento-San Joaquin Delta remains the weak link in California's water supply grid. Approximately 15% of the state's farm and urban supplies comes from the delta. Increasing regulatory pressures and the fragility of the levee network make supplies from the delta increasingly unreliable. Efforts to craft a solution have proven politically difficult and costly. Yet the unsustainable status quo in the delta is harmful to all parties. Resolving the delta conflicts and improving supply reliability are key to managing water scarcity in the Bay Area, the San Joaquin Valley, and Southern California.

Changing Crop Types

To tap favorable world market conditions, farmers have been shifting towards higher-value orchard crops (e.g., almonds, pistachios, wine grapes). From 2000 to 2010, orchard acreage

rose by nearly 20% in the southern Central Valley, reaching 40% of irrigated crop acreage, and this acreage continues to expand during the drought. This expansion, while generating more "cash per drop," also reduces flexibility to cope with droughts in regions that are particularly susceptible to supply cutbacks. It also increases pressure on overtaxed groundwater basins (and provides an added incentive for farmers to accelerate groundwater management to protect their investments).

Declining Environmental Conditions

The continued decline in populations of native fish, wetland and riparian species poses a major challenge for managing water scarcity. These declines affect water supply operations across the state, as water managers struggle to manage the trade-offs between healthy ecosystems and reliable supplies. The trade-offs are particularly acute during severe droughts such as this one.

Summary

The latest drought has highlighted both the strengths and the weaknesses of California's water supply systems. Long-term improvements in the economic efficiency of water use and investments in portfolio approaches to diversify supply and reduce demand have yielded significant benefits. This drought will likely accelerate these trends, resulting in lasting improvements.

However, state and local agencies will also need to invest in resolving some significant challenges. Although recent legislation holds promise for improving groundwater management, the state would benefit from speeding up implementation where possible. The shift to perennial, high-value crops in the Central Valley makes improving groundwater management even more urgent. Finally, the Sacramento-San Joaquin Delta remains the most challenging water supply and ecosystem

health issue in the state. The effectiveness of efforts to improve conveyance, build new storage, resolve groundwater overdraft, and expand water markets will all be reduced if water management in the delta is not resolved.

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Agricultural Irrigation in This Drought: Where is the Water and Where Is It Going?

Josué Medellín-Azuara, Duncan MacEwan, Jay Lund, Richard E. Howitt, and Daniel A. Sumner

In the midst of its fourth year of drought, California now faces an estimated reduction in surface-water availability of 8.8 million acre-feet (maf) out of 29 maf in agricultural applied water statewide. However, groundwater, the buffer water supply during drought, is replacing about 6.2 maf of surface water via additional pumping. This increased groundwater pumping is in addition to the 1.5 maf of annual average groundwater overdraft in the Central Valley. The net reduction of 2.6 maf in the total supply in 2015 may result in about 564,000 acres fallowed statewide, or about 120,000 more acres than last year's fallowing estimates.

California's historical climate is prone to deep and long-lasting droughts. Even in normal years, most of the precipitation occurs during the winter in the northern, eastern and coastal parts of the state, whereas most of the water demand occurs in the summer in the southern Central Valley and the largely urbanized areas on the coast. As a consequence, California has one of the most engineered water supply systems in the world that includes dozens of surface-water reservoirs, aqueducts, pumping stations and other infrastructure, with the Sacramento-San Joaquin Delta as the hub.

Water sources for agriculture in the Central Valley include the Central Valley Project, the State Water Project, local stream diversions, and groundwater pumping. Figure 1 shows the approximate breakdown of water supply for an average year.

Water condition reports from the California Department of Water

Resources (DWR) this year indicated slightly higher precipitation in the Sacramento Valley compared to last year (75% versus 56% of the average by June 18), and reservoirs were around 50% of historical average storage by this time of the year. However, the reservoirs in the San Joaquin Valley and Tulare Lake Basin are near all-time lows and precipitation was only 45% of the historical average.

The drought impacts are especially severe because California's population and share of permanent crops have both increased. Furthermore, the lack of water in 2015, together with impacts of additional groundwater pumping that occurred in 2014, may lower the water table levels enough to decrease pumping capacity in some areas.

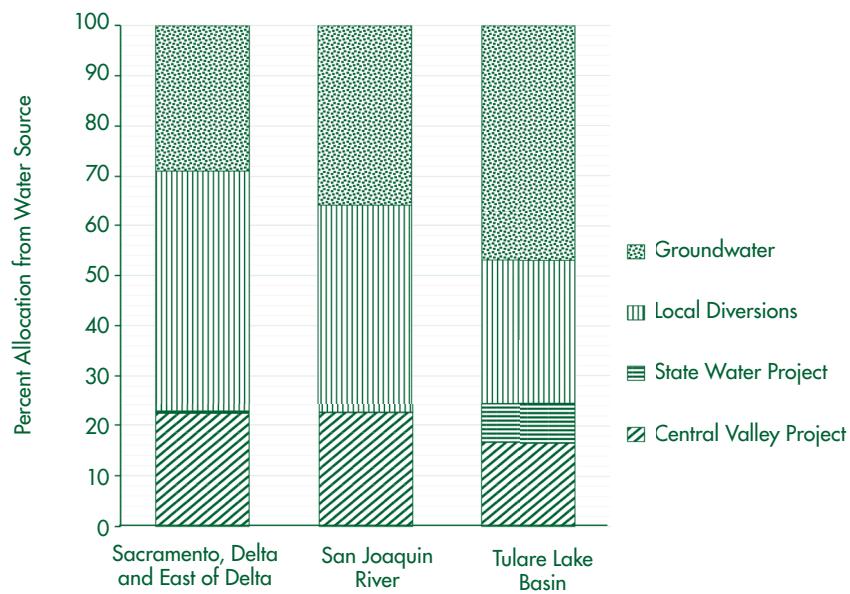
Every year, the state and federal water projects announce deliveries to water districts. Likewise, local water districts across the state inform their member farmers about expected water allocations. Growers, in turn,

make planting decisions based on these expected water deliveries.

In the early spring of 2015, ERA Economics conducted a survey of irrigation districts to assess the expected water deliveries for the irrigation season. The total water shortage is expected to be close to 8.8 million acre-feet (maf) statewide. Farmers and irrigation districts are able to partially offset some of the surface water shortage by pumping additional groundwater. Additional groundwater pumping in 2015 is expected to be 6.2 maf, resulting in a net water shortage of 2.6 maf. The map in Figure 2 shows a breakdown of net water shortages by basin.

The region most affected by water availability is the Tulare Lake Basin, which includes parts of Fresno, Tulare, Kings, and Kern counties. This area has the lowest precipitation and relies heavily on water imports from other basins and groundwater pumping, yet it provides more than 50% of all agricultural revenues in the Central Valley. The

Figure 1. Water Sources for the Central Valley in a "Normal" Year



Source: Author's calculations using CA Department of Water Resources land and water use data

net water reduction of 2.6 maf in 2015 will be 60% higher than 2014 (Table 1).

We used the changes in irrigation water supplies and the Statewide Agricultural Production Model (SWAP) to estimate the crop mix and fallowing due to the 2015 drought. The SWAP model is an economic model, which simulates the response of farmers to changes in water supply. The model includes detailed information on crop acreages, values, and regional access to ground and surface water supplies.

We linked the SWAP model to DWR's groundwater-surface water simulation model, C2VSim. The C2VSim model estimates the groundwater levels and pumping capacities and feeds this information to the SWAP model. Declining groundwater levels increase the energy required to pump groundwater, and in turn the cost of using groundwater for irrigation. The SWAP model simulates the response by farmers to this increased cost of groundwater pumping.

With net shortages of 2.6 maf for 2015, the SWAP model estimates fallowing nearly 564,000 acres statewide—562,000 of which would occur in the Central Valley. Other areas include the Central Coast, the South Coast and inland Southern California, which are less affected by decreased precipitation, have access to groundwater, or import water from other basins such as the Colorado River.

Figure 3 shows a breakdown of estimated fallowing due to the 2015 drought. The bulk of the fallowing occurs in feed and grain crops, in addition to some field crops south of the delta. Fallowing of vegetables, orchards, and vineyards will be minimal, yet the Tulare Lake Basin may fallow some of these higher revenue per acre crops.

We have conducted retrospective analyses of previous droughts and found that the SWAP model accurately estimates fallowing due to water shortages. In addition, we can use multispectral satellite imagery to estimate the total

Figure 2. Estimated Net Water Shortage by Region in the Central Valley for the 2014–2015 Water Year

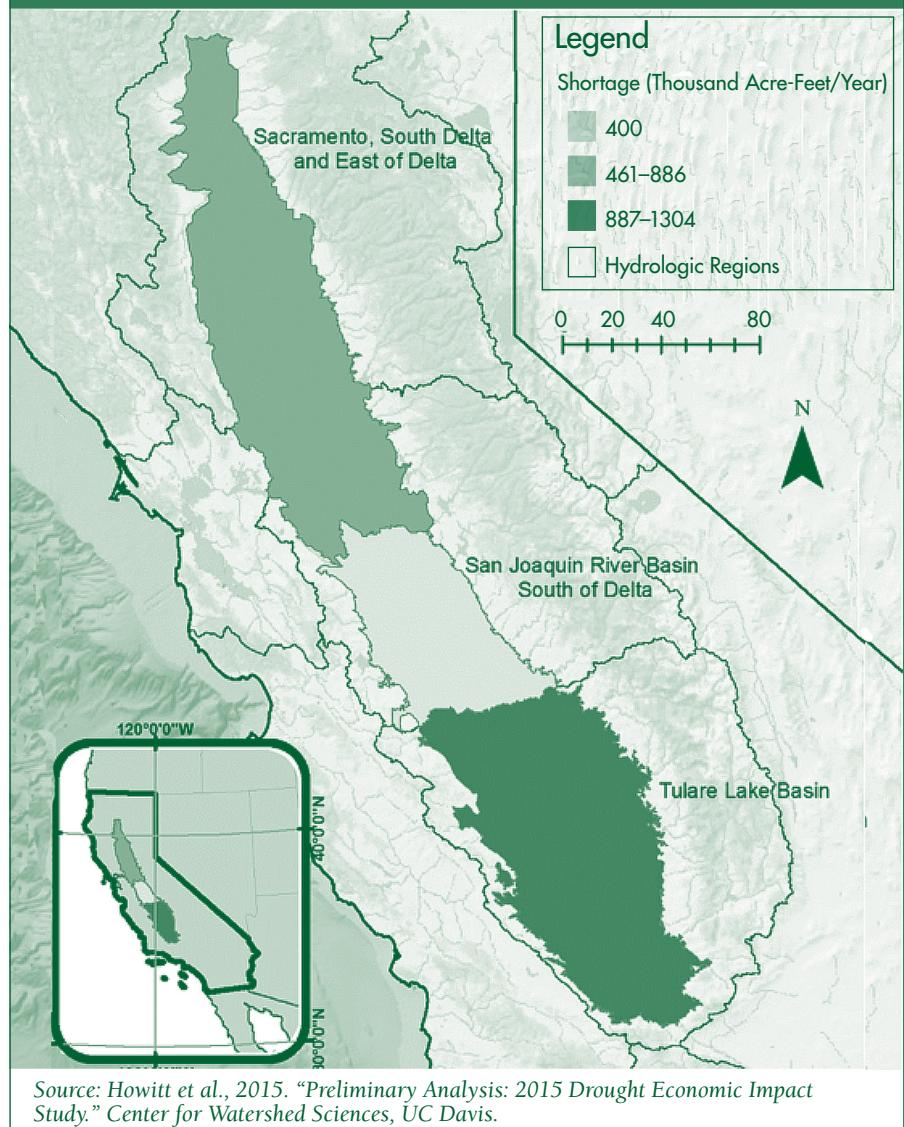
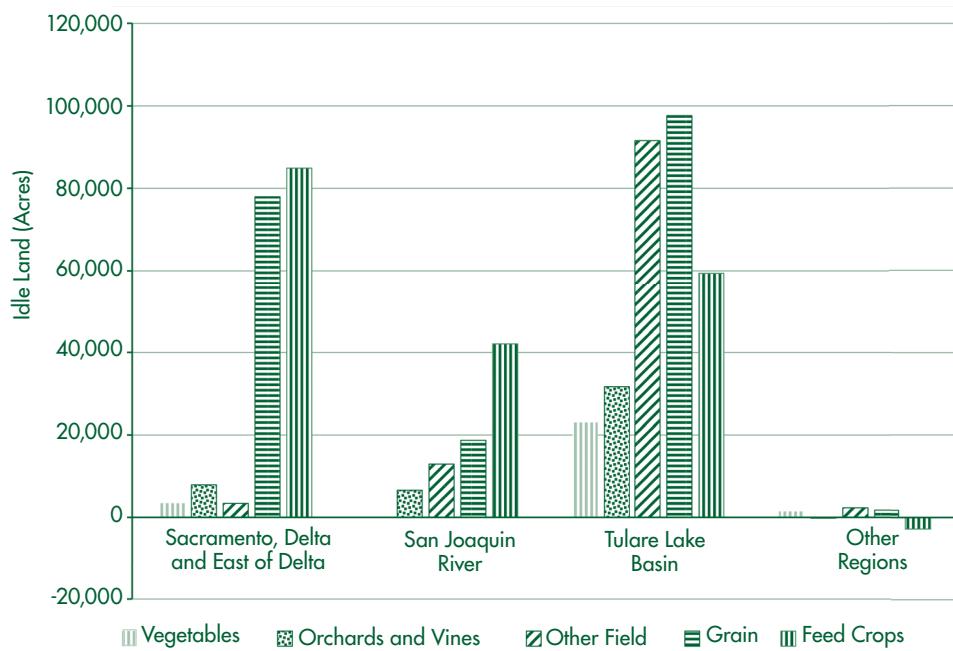


Table 1. Irrigation Water Reductions in the 2015 Compared to "Normal"

Region	Surface Water Change (maf/year)	Additional Groundwater Use (maf/year)	Net Change (maf/year)
Sacramento Valley, Delta and East of Delta	-2.2	1.3	-0.9
San Joaquin Valley	-1.9	1.4	-0.5
Tulare Lake Basin	-4.8	3.5	-1.3
Central Valley Total	-8.8	6.2	-2.6
Central Coast	-0.0	0.0	-0.0
South Coast	-0.0	0.0	-0.0
Colorado River Region	-0.0	0.0	-0.0
Statewide Total	-8.8	6.2	-2.6

Source: Howitt et al., 2015. "Preliminary Analysis: 2015 Drought Economic Impact Study." Center for Watershed Sciences, UC Davis.

Figure 3. Idled Land in 2015 by Region and Crop Group



Source: Howitt et al., 2015. "Preliminary Analysis: 2015 Drought Economic Impact Study." Center for Watershed Sciences, UC Davis.

idle land area using measures such as the Normalized Difference Vegetation Index (NDVI). The NDVI estimates total idle land area, whereas SWAP estimates fallow land due to water shortage.

In May 2014, predicted fallowing using SWAP was 410,000 acres in the Central Valley. We compared 2014 and 2011 NDVI measures and found there were an additional 450,000 acres of idle land in 2014 compared to 2011. Similar estimates by NASA Ames found around 500,000 acres of idle land. We note that SWAP estimates are directly based on water changes, whereas satellite-based estimates measure all idle land. Patterns of idle land are consistent between SWAP and the vegetation index methods, and support the overall conclusion that the bulk of the fallowing occurs in the Tulare Lake Basin.

Conclusions

Our preliminary assessment of the economic impacts of the 2015 drought finds about 2.6 maf less net water available for irrigation. Areas in the Central Valley that rely on surface water imports and have limited access

to groundwater are likely to fallow significant acreage. We estimate that nearly 55% of this fallowing is occurring in the Tulare Lake Basin.

One-third of the fallowing will be in the Sacramento Valley, the delta, and east of the delta. Statewide, about 87% of the fallowing will be in feed crops such as alfalfa, corn and irrigated pasture, as well as grains and other field crops.

Coastal areas and inland Southern California agriculture are likely to have marginal reductions in irrigated land area. In some cases, there will be a slight increase in the production of some crops due to small changes in commodity prices.

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Economic Impact of the 2015 Drought on Farm Revenue and Employment

Richard E. Howitt, Josué Medellín-Azuara, Duncan MacEwan, Jay R. Lund, and Daniel A. Sumner

We estimate that a net water shortage of 2.6 million-acre feet could cause 564,000 acres to be fallowed and result in a loss of \$850 million in crop production value. The surface water shortage of 8.8 million acre-feet will be replaced by about 6.2 million acre-feet of increased groundwater pumping, at a cost of about \$600 million. We estimate the dairy and cattle industries will lose \$350 million in revenues. We estimate the direct economic cost of the 2015 drought will be \$1.8 billion, with a loss of 8,550 direct farm jobs. Including spillover effects, statewide losses are close to \$2.7 billion in output and 18,600 full-time and part-time jobs.

During California's periodic droughts, water shortages lead to fallowing and significant reductions in output from California agriculture. Adaptation methods include changing the typical crop mix by using water for crops with higher revenue per unit of water, substituting groundwater for surface water, water transfers, and additional use of technology.

Estimated changes in water supplies were based on a survey of water districts conducted in the spring of 2015, public announcements of water deliveries from federal and state water projects, and information on groundwater tables from the California Department of Water Resources (DWR) C2VSim model. We used the Statewide Agricultural Production Model (SWAP) to estimate the economic impacts of the 2015 drought. Our preliminary estimates of the impacts of the drought on cropping patterns were reported in Howitt et al. (2015).

We estimated an 8.8 million acre-foot (maf) loss in surface water availability could be partially offset by increased groundwater pumping of 6.2 maf statewide. We used the SWAP model to estimate the additional fallowing of 564,000 acres, and a decrease in crop revenue of about \$850 million. Additional losses for cattle and calves (\$100 million) and dairies (\$250 million), due to reduced winter pasture and higher cost of forage crops, are also expected. The combination of these losses lowers revenue by about \$1.2 billion, compared to a normal water year. We estimate groundwater pumping costs could increase by \$600 million in 2015 as a result of higher pumping volumes and lower groundwater levels.

Crop Revenue Losses

Crop revenue declines vary by region and crop category. Figure 1 shows disaggregated losses. Based on data through late May, our SWAP model estimates that the Sacramento Valley, extending from Shasta County to the

delta, will face revenue losses of over \$200 million in feed and grain crops while maintaining most vegetable and orchard production. More recent data on water availability and planted acreage are likely to raise these estimates.

The northern San Joaquin Valley, from south of the delta to just north of Fresno County, has relatively small losses and even revenue increases for some crops due to slightly higher crop prices for vegetables, orchards, and vines. Other areas, like the Central and South Coast, may also see slight revenue increases. As shown in Figure 1, we estimate that the Tulare Lake Basin will face severe revenue losses totaling about \$620 million across all crop categories.

Jobs and Broader Economic Impacts of the Agricultural Drought

Based on crop fallowing, about 8,550 direct full-time and part-time jobs could be lost, 7,670 in crops and nearly 980 in livestock and dairies. This estimate incorporates the fact that about two seasonal jobs equal one full-time

Figure 1. Changes in Revenue by Crop Category and Region

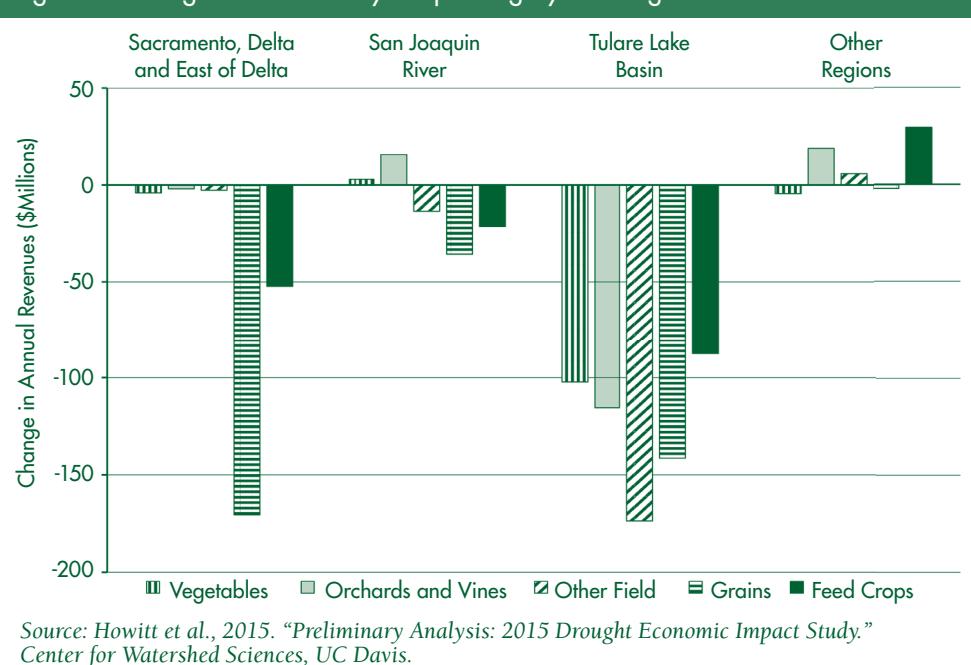
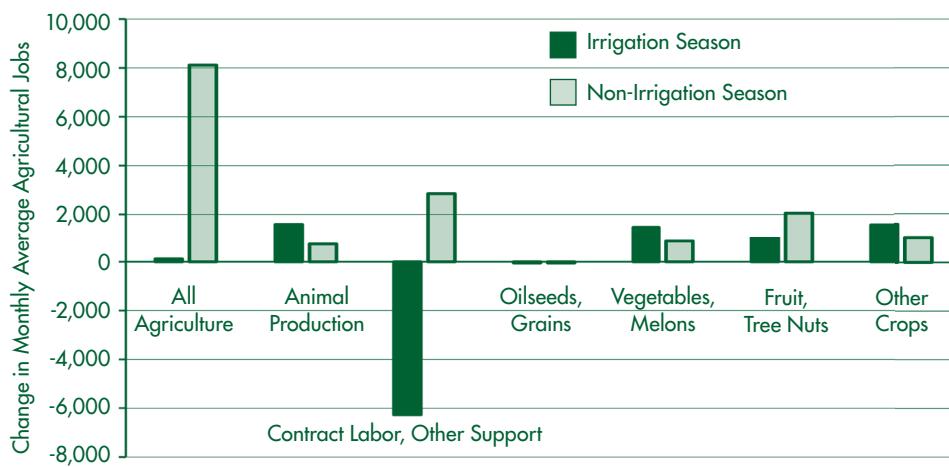


Figure 2. Change in Monthly Average Agricultural Jobs by Season and Commodity Category



Source: Data from the California Employment Development Department

equivalent job. Most employment losses occur in the Tulare Lake Basin. Changes in field crops and grains account for nearly 6,840 of the direct job losses.

Impact analysis allows us to trace expenditure patterns in a regional economy caused by an economic event. When agricultural crop revenues are reduced due to water shortages, expenditures on agricultural-related sectors such as fertilizers, agrochemicals, or farm consulting services are also reduced. These indirect economic impacts cause the direct on-farm impacts to ripple through the economy. Moreover, those households that rely on agriculture and agriculture-related sectors for income spend less on consumer goods and services; these induced

effects also ripple through the economy, reducing economic activity and jobs further. The sum of direct, indirect, and induced effects is often referred to as the total or multiplier effect of an economic event on the region's economy.

Howitt et al. (2015) uses this type of analysis to show the direct and total effects of the agricultural drought in the California economy. Multiplier effects on employment, sector output, and value added are examined. Employment represents full-time and part-time jobs; sector output refers to sales from agriculture and all other sectors in the economy; and value added is a measure of net gain in economic value after netting out any double counting across sectors. Value added includes salaries,

self-employment income, other property income (e.g., corporate income, rent) and indirect business taxes.

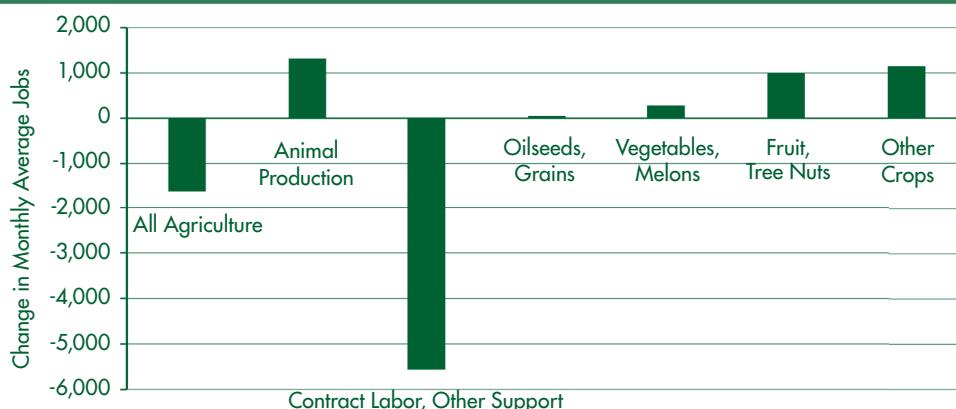
Preliminary estimates in Howitt et al. (2015) show that indirect and induced effects from the 8,550 direct job losses and their spillover effects result in a loss of about 18,600 jobs in California in total. Likewise, direct agricultural revenue losses of about \$1.8 billion generate a loss of \$2.7 billion in state value of output across the whole economy. We estimate a loss of farm value added of \$420 million and an overall loss of \$1.25 billion in California value added.

Understanding Drought Losses in the Context of a Growing Agriculture

Despite the recurrence of droughts, California's \$45 billion agricultural economy has grown in recent decades, as it has shifted to commodities generating more revenue per acre and per acre-foot. This includes an increasing proportion of cropland devoted to tree and vine crops. Many of the expanding crop groups in California, including orchards, berries and vegetables, are more labor intensive than the more mechanized field crop categories.

Impacts of the drought in the context of changes in overall farm employment merit careful examination. For example, Howitt et al. (2014) estimated that the drought would cause a loss of about 7,500 direct farm jobs—almost 2% of about 400,000 farm jobs in California. Recently released annual data show that farm jobs in California (including those hired by farms directly and those hired by labor contractors) rose by about 4,000 jobs, or about 1% from 2013 to 2014 (California Employment and Development Department). This result does not contradict losses due to drought and reinforces the point that labor-intensive agriculture has, in fact, been growing, and job growth would have been larger, but for the continuing drought.

Figure 3. Changes in San Joaquin Valley Agricultural Jobs by Crop Category During the Irrigation Season from 2013 to 2014



Source: Author calculations using data from the California Employment Development Department

Figure 2 shows that while agricultural jobs grew in aggregate, that growth was in the fall and winter months of the 2013–2014 water year, in what is considered the non-irrigation season. The jobs associated with the main irrigated crop production period in the Central Valley, from April to September, showed no change in employment. Figure 3 shows that where irrigation availability declined most in the San Joaquin Valley, irrigation-season jobs fell in total—especially for contract workers.

Figure 4 puts the 2014 employment data into perspective. Agricultural jobs have grown in California in each of the last five years from 2010 to 2014, especially in the non-irrigation season. Growth was faster in the two pre-drought years and 2014 was the second lowest. Much of the non-irrigation season employment occurs in coastal regions with year-round employment in berries and vegetables—crops that are minimally affected by the drought.

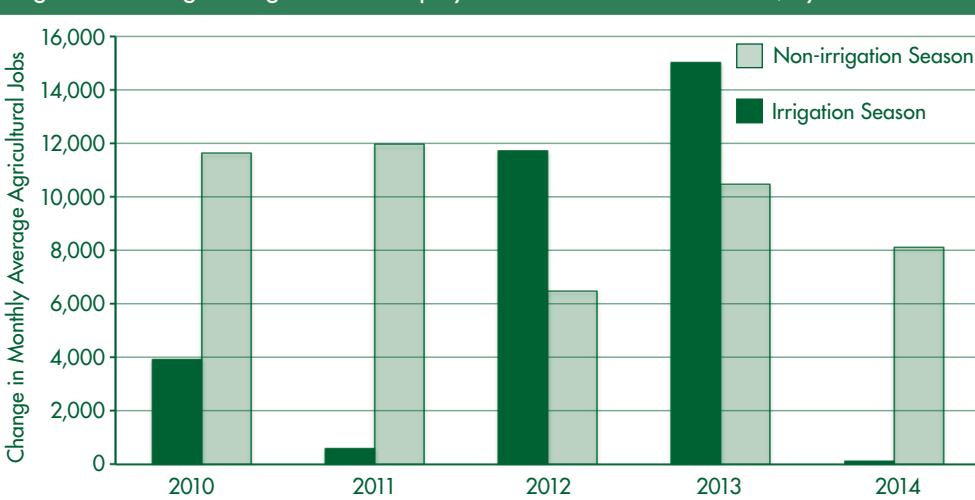
Irrigation season employment, which is important in the Central Valley and is affected by drought, failed to grow in 2014—the only time in this five-year period—after substantial growth in every year except 2011. These data are consistent with substantial drought-induced job losses for some of the most vulnerable workers in California in 2014 and again in 2015.

Conclusions

Droughts in California pose substantial challenges for agriculture. Yet the water system supporting agriculture has proven resilient in past droughts. The current drought is causing large economic losses but given innovative responses by farmers and others, those losses have been manageable and California agriculture is positioned to weather this drought.

Groundwater has again been instrumental in replacing much of the loss of surface-water deliveries during the drought. With that said, continuous

Figure 4. Change in Agricultural Employment from the Previous Year, by Season



Source: Author calculations using data from the California Employment Development Department

overdraft of groundwater, a fast-growing proportion of permanent crops, and the use of irrigation systems that minimize recharge reduce the ability to cope with future droughts. Innovations in legal and regulatory institutions and in irrigation incentives are needed to reduce overdraft and renew efforts to recharge underground aquifers for future use.

The 2015 agricultural drought will be costly for farmers, workers, and the California economy. We estimate losses of 18,600 jobs and \$2.7 billion in output. California agriculture is diverse and the effects of drought differ by region and crop category. The largest losses are in field crops and in the Central Valley. Regions with smaller irrigation water cutbacks, such as the Central Coast, have relied on groundwater to maintain production. Where these regions tend to grow labor-intensive crops, employment has continued to expand. But, of course, this does not relieve much stress in those regions with severe losses in output and employment.

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California's Severe Drought Has Only Marginal Impacts on Food Prices

Daniel A. Sumner

Flexibility and resourcefulness by California farmers have minimized drought-induced supply reductions for tree, vine and vegetable crops, for which California has large market shares and for which retail prices would be sensitive to California disruptions. Water is being shifted away from field crops that enter the food supply indirectly and for which California is not a dominant producer. These facts mean that even a severe drought is having only slight impacts on supplies to consumers and thus only slight impacts on consumer food prices. Of course, the longer the drought lasts, the larger the impacts.

The Simple Economics of Farm Production and Retail Food Prices

Food price changes follow from farm commodity supply and demand conditions. So if the drought reduces farm supplies and raises farm costs, then prices of food products derived from those farm commodities must rise. How much each food product price rises due to the drought depends on several common sense determinants:

- The magnitude of the supply reduction or farm cost increases for the commodities used in each of the food products.
- The share of the relevant commodity supply that is affected by the drought.
- The relative shares of the farm cost and other post-farm processing and marketing costs in the retail price of the related food product.
- The availability of substitutes for the food products affected.

The magnitudes of each of these determinants is different for each farm commodity affected by the drought, and we will discuss each in turn for major commodities.

California Commodity Supply Reductions and Cost Increases Caused by the Drought

As the previous articles in this *ARE Update* issue document, the California drought is likely to reduce acreage by close to 10%. But, almost all that reduction in acreage is occurring in the Central Valley and among the major forage, grain and other field crops, for two reasons.

First, in normal years, Central Valley agriculture relies on surface water deliveries from major government-owned or regulated projects. That means crops

grown in the Central Valley have been more subject to government mandated water cuts than crops grown in regions with a higher reliance on groundwater or local deliveries.

Crops such as fresh vegetables, berries, avocados, and high-priced winegrapes are grown mostly in regions that have faced fewer mandated cuts in water supplies. Crops such as tree nuts and tree fruit, lower-priced winegrapes, and field crops tend to be grown in the Central Valley where they have been subject to more surface water cutbacks (Table 1).

Second, when droughts occur, farmers have strong incentives to shift water to crops with higher net revenue per acre-foot of water in order to minimize economic losses. Forage crops such as hay, corn silage, irrigated pasture, grain crops, and other field crops have much lower revenue per acre and require more acre-feet of water than tree and vine crops or vegetables (Table 1).

During a drought year, multi-crop farms have strong incentives to reallocate their water to crops that generate more potential profit or at least minimize losses—including losses of capital invested in orchards and vineyards. A farm growing say, grapes and wheat, will naturally leave the wheat field unirrigated to save water and keep vines alive and productive. And, farms that have the physical and legal ability to shift water to others, will naturally be more willing to transfer water away from low revenue per acre field crops and toward other farms, either nearby or, often, much further south, that use water for tree nuts, fruits, or vegetables.

Geography and irrigation infrastructure reinforces the tendency for concentrating supply reductions on field crops. The primary regions for growing fresh vegetables and berries in California

The severe drought that California has been experiencing for several years has idled hundreds of thousands of acres of cropland, reduced crop yields, cut the cattle herd on pastures throughout the state, and reduced farm production value by billions of dollars. Nonetheless, despite the fact that California is the most important farm state in the United States—leading the nation in production of major commodities such as milk, tree nuts and many fruits and vegetables, and supplying about half of U.S. fresh produce—most consumers have seen no sign of the drought in the cost of food. This article lays out the facts and economic logic for why this is true.

The previous articles in this issue have sketched the severity of this drought and what it has meant for irrigation water costs and availability, crop planting patterns, and production. This article takes the story through to food consumers.

include the central and southern coastal valleys and Imperial County. Imperial County receives irrigation water from the All American Canal and the Colorado River system, thus insulating the region from this California drought. The coastal valleys have had low precipitation but rely primarily on local groundwater aquifers that have not been under as much pressure during this drought as those in the Central Valley.

Table 1 lists lettuce as the representative fresh vegetable crop, but the Central Coast is also home to most production of crops such as celery, broccoli, and spinach. The Central Coast, from Santa Cruz County down the coast to Ventura County, also produces most of the strawberries and raspberries. The high revenue per acre and per acre-foot of water for crops such as strawberries and lettuce also provide great incentives to apply the irrigation water needed to sustain production.

Irrigation water per acre varies widely by crop and region, from around one acre-foot per acre for winter and spring vegetables grown in cool coastal regions with ample humidity, up to perhaps five acre-feet per acre for some trees and alfalfa in the hot and dry southern San Joaquin Valley. Of course, crop yields are also high where irrigation use is high.

Water costs per acre-foot also vary widely from lows of \$20 to \$50 per acre-foot for surface water in the north, in places where water has been plentiful or where groundwater tables are near the surface. Regular pumping costs or delivery costs can exceed \$1,000 per acre-foot in some regions and during drought periods. (During this drought, limited amounts of water have been transferred at even higher prices, especially when farmers needed to keep trees and vines alive or pay urban prices for very high revenue crops.) In general, however, it is clear that where physically feasible and allowed by

Table 1. Revenue per Acre and Growing Region for Selected California Commodities, 2013

Commodity	Revenue/Acre	California Growing Region
Almonds	\$6,867	Central Valley
Cattle and Calves (Beef)	--	Foothill and Mountain
Grapes	\$6,812	Central Valley & Coastal
Hay, Including Alfalfa	\$1,090	Central Valley, Mountain and Imperial
Lettuce	\$8,459*	Coastal and Imperial
Milk	--	Central Valley
Peaches	\$6,050	Central Valley
Rice	\$1,408	Sacramento Valley
Strawberries	\$53,030	Coastal
Tomatoes, Processing	\$3,532	Central Valley
Wheat	\$663	Central Valley

Source: USDA, "California Agricultural Statistics, Crop Year 2013."

*Single crop only. Land often has multiple crops per year.

regulation, farms will tend to use available water on tree, vine, and a few other crops while shifting water away from field crops.

The drought affects California production of livestock commodities mainly through impacts on forage crop output. Poultry, egg, dairy, and finished beef production relies mostly on grains shipped in from other states. But, California-produced hay, silage, and irrigated pasture are important for cattle. Hay and silage, mostly produced in California, comprise about 20% of California milk production costs. Therefore, a 50% increase in costs of hay and silage due to the drought would increase milk production costs at the farm by a bit less than 10%.

Market Shares and Effects on Farm Prices

Many observers point to the large share of California produce in the nation's supply. Table 2 indicates California's large share of U.S. production for tree, vine, and vegetable crops. These are the crops for which the current drought is not causing large supply cuts.

California has smaller market shares for livestock and field crops where California supply reductions are large. These facts mean that even when Cali-

fornia supply falls significantly, say for wheat, rice or hay, the amount in the U.S. or relevant global market falls by a much smaller percentage. Two caveats affect the interpretation of these production shares.

First, for some important crops, the relevant markets are global. For example, Table 2 indicates that about two-thirds of California almonds and about half of California rice are exported. Global market share is crucial. For almonds, California also has a large share of the global market so if supply were to fall (as has not happened much during this drought), price would indeed rise.

Exports are also important for dairy products, processing tomatoes, and rice. Markets for each of these commodities faces particular conditions. In the case of milk and tomatoes, California ships processed products into competitive national and global markets. For rice, California is a tiny part of global markets, but produces a specialized style of rice for which California production shortfalls do affect price somewhat.

Finally, in the case of wine, imports matter as well as exports. While California dominates U.S. wine production, the market is quite competitive—especially in the case of wine from

Table 2. Share of U.S. Production and Export Ratio of Production for Selected California Commodities, 2013

Commodity	CA Share of U.S. Production Percent	Export Ratio of Production
Almonds	99	0.67
Cattle and Calves (Beef)	5	0.09
Grapes	89	0.20
Hay, Alfalfa and Other	6	0.21
Lettuce	78	0.10
Milk	21	0.30
Peaches	72	0.11
Rice	25	0.47
Strawberries	88	0.08
Tomatoes, Processing	96	0.31
Wheat	2	0.14

Sources: USDA, "California Agricultural Statistics, Crop Year 2013," and UC Agricultural Issues Center, "2013 California Export Data."

Central Valley grapes that are most likely to be affected by drought.

Marketing Costs and Retail Demand Conditions

Of course, farm price changes are not the only driver of retail prices. Costs added along the marketing chain to the final consumer often add as much or more than farm costs. For example, the farm share of retail cost for strawberries or lettuce is 30% but only about 7% for bread. These relationships mean that even if prices rise at the

farm, the percentage impact for retail consumers is generally muted—and more muted for processed products and those subject to costly and specialized marketing and transport.

Flexibility by retailers and consumers also moderates price impacts. Given that drought has slowly evolving impacts with substantial warning, wholesale and retail buyers have ample time to plan ahead and source products from where they are most available. Finally, many consumers are willing to substitute across products such as types

of melons or lettuce, or from table grapes to some other fruit if relative prices change.

Summary of Retail Price Impacts of the Drought

A simple pair of equations summarizes the expected percent change in retail price caused by a change in quantity supplied of the associated California farm commodities. First consider the farm price impact:

$$\%change P_{farm} =$$

$$(1/e) S_c (\%change Q_{Calfarm})$$

where $\%change P_{farm}$ is the farm price of the commodity, e is the own price elasticity of farm demand for the commodity, which measures how much quantity demanded falls when price rises, S_c is the share of California production in the market supply, and $\%change Q_{Calfarm}$ is how much the quantity produced in California will fall due to the drought. To simplify the calculation, in this equation I assume farms do not add to production in response to the drought-induced higher price.

The relationship between the change in farm price and percentage change in the retail prices is given by the simple proportionality:

$$\%change P_{retail} = S_r (\%change P_{farm}),$$

where P_{retail} is the price of the retail commodity, and S_r is the farm commodity share in the retail price of the product. Putting these two equations together tells us how the drought is likely to affect the retail price of each item.

Using these relationships, we will consider price impacts for four retail products for which California supply plays an important role in the national market: cheese, lettuce, rice, and wine. Table 3 shows the parameters and results for each product.

Table 3. Expected Effects of the California Drought on Retail Prices of Cheese, Lettuce, and Rice

	Cheese	Lettuce	Rice	Wine
Farm Share of Retail Price	0.3	0.3	0.3	0.1
Own-price Elasticity of Retail Demand	-0.3	-0.5	-0.5	-0.5
California Share of Relevant U.S. Market	0.2	0.8	0.5	0.5
Percent Change in Quantity Supplied by California Farms	-5%	-3%	-33%	-1%
Percent Change in Retail Price	1%	1.5%	10%	0.1%

Sources: Author estimates based on data from USDA, California Agricultural Statistics, Crop Year 2013; USDA ERS, "Price Spreads from Farm to Consumer," www.ers.usda.gov/data-products/price-spreads-from-farm-to-consumer.aspx#2565; Abigail M. Okrent and Julian M. Alston, "Demand for Food in the United States: A Review of Literature, Evaluation of Previous Estimates, and Presentation of New Estimates of Demand," Giannini Foundation Monograph 48, April 2011, <http://giannini.ucop.edu/monograph.htm>; and personal communication from Dr. James Lapsley, June 25, 2015.

California produces about 20% of the U.S. milk supply, which can be processed into cheese. The farm share of the retail price for cheese is about 30%. That is, the price of milk before it has been processed into cheese makes up 30% of the cheese retail price. The own-price elasticity of demand for milk, a measure of the responsiveness of quantity demanded to a given change in price, is -0.3. Given the reduced hay and forage supplies to the dairy industry and associated higher prices, we estimate that California milk production may decrease by 5% due to the drought. Plugging these parameters into the equation tells us that the retail price of cheese would increase by 1%.

California is the dominant supplier of fresh produce in the U.S. during much of the year, and its share of the U.S. lettuce market is about 80%. Given a 3% decrease in the quantity of lettuce supplied by California farms, retail price would increase by about 1.5%.

California produces japonica rice for the U.S. and international markets. California rice accounts for about half of the relevant U.S. market, some of which uses specialized California rice and some of which uses medium grain rice produced elsewhere. The market share and demand elasticity reflect that California rice is unique for certain uses in some markets and has close substitutes for other uses. Because of severe reductions in surface water availability, California quantity of rice will likely fall by about 33%, and is therefore likely to cause a 10% increase in retail price.

As a highly processed farm product, grapes account for only about 10% of the retail price of wine. We use an average elasticity of demand for wine-grapes of about -0.5. We estimate that California makes up about half of the relevant market for U.S. wine sales, with imports comprising much of the rest. The reduction in grape quantity of only 1% due to the drought reflects the relatively low share of water costs in



Despite drought, produce from California will remain plentiful for consumers.

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grape production costs and the limited supply flexibility for a perennial crop. These parameters imply the drought is likely to cause an increase in the retail price of California wine of about 0.10%.

Summary and Concluding Remarks

Flexibility and resourcefulness by California farmers have minimized the supply reductions of precisely those tree, vine and vegetable crops for which California has large market shares. Crop production is being cut for field crops that enter the food supply indirectly and for which California is not a dominant producer. These facts mean that even a severe drought is having only slight impacts on supplies to consumers and thus only slight impacts on consumer food prices. Of course, the longer the drought lasts, the larger the impacts. But for the foreseeable future, California farms will remain reliable suppliers of tree nuts, fruits, vegetables, dairy products and much more.

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