

Economic Analysis of the 2015 Drought For California Agriculture



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Executive Summary

In 2015 California agriculture is facing its fourth year of severe drought. As in 2014, irrigation districts and farmers are showing more resilience to the drought than many had anticipated.

Groundwater substitution has again greatly reduced crop following and job losses. Water trading and operational flexibility also have significantly reduced the costs of the drought, and preservation of the most valuable crops has helped buffer economic impacts.

However, the effects of drought are unevenly distributed over regions. In some regions with limited groundwater reserves the economic and employment impacts are very severe. In others, there is an increased cost of expanded groundwater use which is partially offset by high crop prices.

Just as the economic impacts of the drought have grown modestly since 2014, continuation of the drought to 2016 or beyond with similar intensity is likely to slowly erode the state's agricultural production and employment.

Table ES-1. Summary of impacts of the 2015 California drought

Description	Impact	Base year levels	Percent change
Surface water shortage (million acre-ft)	8.7	18.0	-48%
Groundwater replacement (million acre-ft)	6.0	8.4	72%
Net water shortage (million acre-ft)	2.7	26.4	-10%
Drought-related idle land (acres)	540,000	1.2 million*	45%
Crop revenue losses (\$)	\$900 million	\$35 billion	2.6%
Dairy and livestock revenue losses (\$)	\$350 million	\$12.4 billion	2.8%
Costs of additional pumping (\$)	\$590 million	\$780 million	75.5%
Direct costs (\$)	\$1.8 billion	NA	NA
Total economic impact (\$)	\$2.7 billion	NA	NA
Direct job losses (farm seasonal)	10,100	200,000 [#]	5.1%
Total job losses	21,000	NA	NA

* NASA-ARC estimate of normal Central Valley idle land.

[#]Total agriculture employment is about 412,000, of which 200,000 is farm production.

Our estimation of economic impacts controls for confounding factors. Changes in irrigation water deliveries, derived from reported deliveries and a survey of irrigation districts, were used to estimate the economic responses of farmers, including additional groundwater pumping, water market purchases, and planting and fallowing decisions.

By using changes in water availability to estimate economic impacts, we avoid problems from ascribing all changes in aggregate economic production and employment to the drought. Changes in business conditions, commodity prices and other factors also affect agricultural revenues and employment, regardless of hydrologic conditions. It is important to control for these factors to isolate the impact of drought. Table ES-1 summarizes our estimates of the impact of the 2015 drought.

California agriculture's resilience to surface water shortages is likely to continue through 2015. The ability to irrigate permanent crops with groundwater or marketed water will largely prevent the sector from more expensive fallowing of higher-valued crops and permanent crops. Some major conclusions:

- Surface water shortages of nearly 8.7 million acre-feet will be mostly offset by increased groundwater pumping of 6 million acre-feet. Groundwater offsets almost 70% of the drought water shortage. Virtually all water shortages will be in the Central Valley.
- Net water shortages of 2.7 million acre-feet will cause roughly 542,000 acres to be idled – 114,000 more acres than the 2014 drought estimate. Most idled land is in the Tulare Basin. Temperature control and other regulations may exacerbate the projected land idling, particularly in future years.
- Direct agricultural costs of drought will be about \$1.84 billion and 10,100 direct seasonal jobs. When multiplier effects are considered, losses to all economic sectors will be as high as \$2.74 billion and nearly 21,000 total jobs.
- The effects of continued drought through 2017 (assuming continued 2014 water supplies) will likely be 6% worse than in 2015, with the net water shortage increasing to 2.9 million acre-feet per year. Gradual decline in groundwater pumping capacity and water elevations will add to the incremental costs of a prolonged drought.
- Increased groundwater overdraft during drought will slowly deplete groundwater reserves at an incremental cost. New groundwater regulations could eventually reverse this trend and force groundwater basins towards sustainable yields. The transition will cause some increased fallowing or longer crop rotations, but will preserve California's ability to support more profitable permanent and vegetable crops through drought.

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Cover photo by Chris Austin

Introduction

California is in a fourth year of drought – with the last two years being among the driest and warmest individual years on record – raising concerns at all levels, especially in agriculture. Many water districts are intensively using carryover surface and groundwater reserves to ease surface water scarcity. Active ad hoc water markets and other innovations have further softened the economic impacts. Overall, California agriculture remains resilient to this drought thanks to continued growth in value of products, successful local, regional and statewide water management actions, and the state’s vast, yet slowly declining groundwater reserves.

We estimate the economic impact of the 2015 drought on agriculture and the effects of continued severe drought in 2016 and 2017. Our research team assessed water availability for agriculture based on groundwater access estimates, recent surveys of more than 80 irrigation districts, and announcements from federal, state and local projects.

We briefly describe the modeling approach and assumptions and summarize the results. Water availability assessment and groundwater information are detailed in the report appendices.

Modeling Approach

The study employed a suite of models using primary data from irrigation district surveys and secondary information from public sources. The approach follows methods described in Medellín-Azuara et al. (2015) and used in the 2014 drought impact study on California agriculture (Howitt et al., 2014). Water availability assessments and access to groundwater are key inputs to the SWAP model (Howitt *et al.*, 2012), which is the backbone of the study. SWAP simulates decisions by farmers in the statewide agricultural market across 20 crop groups in 38 regions, representing most of California’s farm commodities and irrigated acreage.

We use results from the surface-groundwater simulation model C2VSim in the SWAP economic model. The C2VSIM model simulates water table depths using pumping quantities based on the SWAP crop mix and surface water allocations. The cost to pump groundwater for irrigation increases as the water table falls. The direct economic cost of the drought is primarily driven by the increased pumping costs, changes in the crop mix, land fallowing, and corresponding livestock and dairy losses. We use the IMPLAN input-output model to estimate the statewide multiplier effects and job losses resulting from these direct economic costs.

Data for this economic assessment came from the following sources:

- A survey of irrigation districts during spring and mid-summer 2015 (see summary in Appendix A)
- Announced Central Valley Project (CVP) and State Water Project (SWP) deliveries

- Estimated changes in groundwater levels using DWR’s C2VSim groundwater model
- Estimated water market transfers between and within districts.

Changes in Water Availability

Changes in water availability for the 2015 drought are based on announced deliveries from the CVP and SWP, surveys of irrigation districts, the ability to replace surface water with groundwater in the short-term (using 2006-2010 well-pumping data), and the C2VSim model. Figure 1 below summarizes reductions in agricultural water availability.

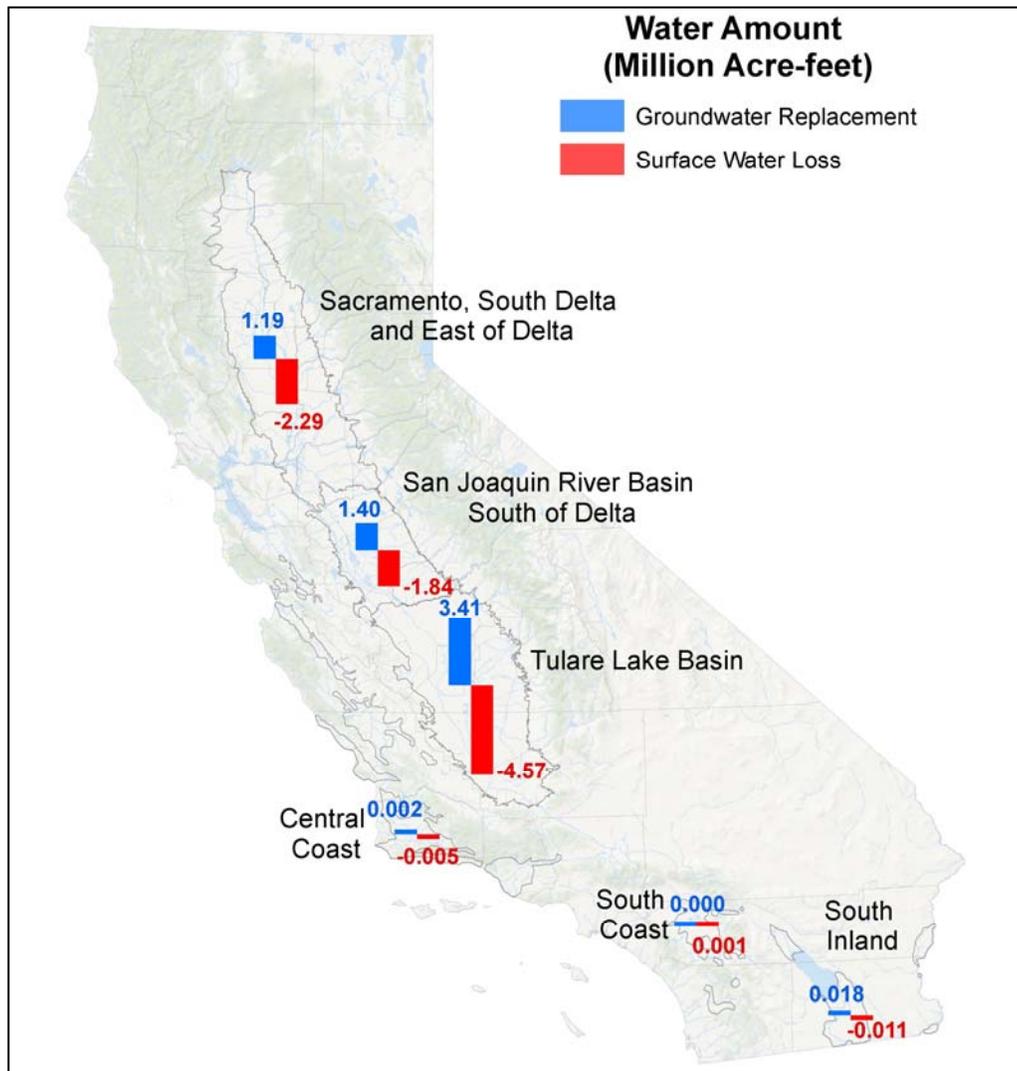


Figure 1. Estimated changes in water availability for 2015 drought by region.

We estimate the 2015 drought has reduced surface water by 8.7 million acre-feet statewide. This shortage has been partially offset by a 6 million acre-foot increase in

groundwater pumping for an estimated net shortage of 2.7 million acre-feet. Table 1 shows estimated surface water shortages by region and the estimated ability to replace lost surface water with groundwater.

We additionally consider the economic impacts if the drought continues in 2016 and 2017. We model the impact of 2016 and 2017 drought under the current (2015) surface water availability. We make some additional adjustments for additional curtailments, changes in groundwater availability and elevations, and transfers discussed more below. Table 1 summarizes the surface water availability under the 2015 and 2016-2017 droughts.

Table 1. Estimated Change in Water Use, 2015 drought (million acre-feet)

2015			
Region	Surface Water	Groundwater	Net Delivery Shortage
Sacramento	-2.29	1.19	-1.1
San Joaquin	-1.84	1.40	-0.44
Tulare	-4.57	3.41	-1.16
Central Coast and So. Cal.	-0.02	0.02	0.01
Total	-8.72	6.02	-2.7
2016			
Region	Surface Water	Groundwater	Net Delivery Shortage
Sacramento	-2.35	1.23	-1.12
San Joaquin	-1.87	1.40	-0.47
Tulare	-4.57	3.36	-1.22
Central Coast and So. Cal.	-0.02	0.02	0.01
Total	-8.80	6.00	-2.80
2017			
Region	Surface Water	Groundwater	Net Delivery Shortage
Sacramento	-2.40	1.28	-1.12
San Joaquin	-1.90	1.40	-0.50
Tulare	-4.57	3.31	-1.26
Central Coast and So. Cal.	-0.01	0.02	0.01
Total	-8.88	6.01	-2.87

Sacramento River Temperature Management Plan

The Sacramento River Water Temperature Management Plan monitors water temperatures at Shasta Reservoir to ensure flows are cool enough to support fish habitat. If the water temperature exceeds certain threshold levels, then irrigation districts must curtail surface water diversions. This could have significant economic costs depending on when these curtailments occur.

We finalized this drought impact report in the late summer of 2015 and at the time of publication there were no temperature curtailments in effect. This late in the irrigation season, mid-August, it is unlikely that any curtailments would have a significant economic impact. Many crops are ready for harvest and could get by on residual soil moisture and skip the final irrigation. Alternatively, fields that do need additional irrigation would likely secure that water from other growers in the district. In our analysis of 2016 and 2017 extended drought impacts we do allow for water temperature curtailments.

Water Transfers and Crop Shifts

Water transfers and shifts in crop contracts have an important effect on the impact of drought. We have found that these factors are most important in the Sacramento Valley where significant water transfers, an increase in processing tomato production, and increased perennial plantings has significantly shifted field crop and rice acreage.

In 2015 the accepted price for water is an average of \$650 per acre-foot in our district surveys. This generates substantially more revenue per acre than rice or other field crops grown in the Sacramento Valley. While farmers have shown some reluctance to transfer large amounts of water there are some active transfers in the Sacramento Valley, and this is one reason for the decline in rice acreage in that region.

Processing tomato contracts have shifted north from the San Joaquin to the Sacramento Valley, also pushing out some rice acreage. Favorable weather, strong prices, and low disease pressure in 2015 are likely to result in another increase in processing tomato production this year.

Almond and walnut acreage has increased by more than 200,000 acres statewide since 2010. These new plantings were previously planted mostly to fields growing cotton, irrigated pasture, grains, and hay. Young orchards require less water than many of these field crops and older established orchards. This market-driven shift to perennial crops is not a result of drought.

Modeling Results

This section provides estimates of the costs of drought to crop farming, livestock and dairies statewide. We estimate the impact of 2015 drought and extended drought in 2016 and 2017 using the modeling framework described above. The SWAP model

estimates the profit-maximizing crop mix for a three-year drought starting in 2015. We express drought impacts in terms of revenue losses, additional pumping costs, and jobs.

Irrigated Crop Areas

We estimate the 2015 drought may result in the following of 542,000 irrigated acres, almost all (99.5 %) in the Central Valley. Table 2 summarizes changes in irrigated acreage by region. These figures differ from estimates in the May 2015 preliminary analysis because water transfers, groundwater pumping, and surface water deliveries have changed since our preliminary analysis.

Increased prices for some crop groups will add to the total revenues in areas less affected by drought and with access to groundwater, especially in the central and south coast regions. Feed, grain, and field crops have the largest proportional cuts in irrigated acreage under drought conditions because they hold a lower value per unit of water.

Continued drought through 2016 and 2017, assuming 2015 water conditions for both years, shows a slow decline in the water tables, and following increasing by a few thousand acres, reaching nearly 550 thousand acres by 2017. If access to groundwater were to decrease or agriculture were to face additional curtailments for environmental flows, temperature, salinity, or other factors, the impact of drought in 2016 and 2017 would increase substantially.

Table 2. Estimated Change in Irrigated Crop Acreage from Drought (thousands of Acres)

2015						
Region	Vegetables	Orchards and Vines	Feed Crops	Other Field	Grain	Total
Sacramento	-0.3	-4.4	-37.0	0.6	-138.1	-179.2
San Joaquin	0.1	-4.5	-38.2	-8.4	-21.4	-72.5
Tulare	-22.3	-27.3	-58.5	-90.1	-89.9	-288.0
Central Coast and So. Cal.	-1.2	0.2	2.0	-2.0	-1.4	-2.5
Total	-23.6	-36.0	-131.7	-99.9	-250.9	-542.1
2016						
Region	Vegetables	Orchards and Vines	Feed Crops	Other Field	Grain	Total
Sacramento	-0.4	-4.5	-37.4	0.5	-138.4	-180.2
San Joaquin	-0.1	-4.6	-38.9	-9.3	-21.6	-74.6
Tulare	-22.1	-27.3	-58.8	-89.9	-89.9	-288.1
Central Coast and So. Cal.	-1.2	0.2	2.0	-2.0	-1.4	-2.5
Total	-23.8	-36.2	-133.2	-100.8	-251.4	-545.4
2017						
Region	Vegetables	Orchards and Vines	Feed Crops	Other Field	Grain	Total
Sacramento	-0.5	-4.7	-38.0	0.4	-139.0	-181.8
San Joaquin	-0.3	-4.9	-39.8	-10.4	-21.7	-77.1
Tulare	-22.1	-27.3	-59.1	-90.0	-90.1	-288.5
Central Coast and So. Cal.	-1.3	0.2	2.1	-2.0	-1.5	-2.5
Total	-24.2	-36.6	-134.8	-102.1	-252.3	-549.9

Direct costs of drought

Economic impacts for crop farming can be divided into crop revenue losses, livestock losses, and additional pumping costs. These economic losses are described below.

Crop revenue losses

We estimate total crop revenue losses of \$902 million in 2015. Table 3 summarizes the change in total crop revenues by region and crop group for the three year drought. Following the trend in the drought following for 2016 and 2017, we estimate total gross revenue losses from crops under a continued drought increase to nearly \$940 million by 2017.

Table3. Estimated Change in Crop Revenues due to Drought, 2015 (millions of dollars)

2015						
Region	Vegetables	Orchards and Vines	Feed Crops	Other Field	Grain	Total
Sacramento	8	12	-18	1	-293	-289
San Joaquin	4	17	-19	-8	-43	-49
Tulare	-101.	-111	-90	-172	-131	-604
Central Coast and So. Cal.	-4	16	24	6	- 2	39
Total	-93	-66	-103	-173	-469	-903
2016						
Region	Vegetables	Orchards and Vines	Feed Crops	Other Field	Grain	Total
Sacramento	8	12	-18	1	-295	-292
San Joaquin	2	16	-20	-11	-44	-57
Tulare	-101	-112	-92	-174	-134	-612
Central Coast and So. Cal.	-4	16	25	6	- 2	40
Total	-95	-68	-105	-178	-475	-921
2017						
Region	Vegetables	Orchards and Vines	Feed Crops	Other Field	Grain	Total
Sacramento	7	12	-18	1	-298	-296
San Joaquin	-1	14	-23	-13	-45	-67
Tulare	-101	-113	-95	-175	-135	-618
Central Coast and So. Cal.	-4	16	26	6	- 2	42
Total	-99	-71	-110	-181	-480	-939

Central Coast and Southern California regions benefit from slightly higher commodity prices due to decreased production in other parts of the state. For example, lower hay production in the Central Valley increases hay revenues for Southern California and somewhat lower berry and wine grape production in the Central Valley increases berry and wine grape revenue slightly in the Central Coast relative to normal conditions.

The impact on labor differs between regions. For example, the direct labor impacts in the Sacramento Valley for the grain crop group are substantially higher than in the Tulare region. However the indirect and induced effects are higher for employment in the Tulare Lake basin.

Livestock and Dairies

Losses to California's dairy and cattle and calf industries derive primarily from higher costs and lower availability of California-produced forage, including hay, silage and pasture. Some of the hay and silage is produced on livestock farms where the forage is used, but significant amounts are also sold in spot markets for which prices are recorded. Most high quality alfalfa and most silage, including corn and small grain silage are used on dairy farms. Much non-irrigated rangeland pasture is owned by the cattle operations themselves, but some pasture also is leased to cattle operations, with payments per animal unit grazed. Irrigated pasture is used by cattle operations as supplemental feed during part of the year and by dairy operations for replacement heifers prior to entering the milk cow herd.

Despite low milk prices in 2015, the dairy industry generates more revenue than any other farm commodity in California. The drought has reduced availability of California hay and silage and raised prices above where they would otherwise be in a year with very low milk prices. Alfalfa hay shipments to the dairy region (the San Joaquin Valley) are down relative to 2013 and 2014, although the lower ability to pay by dairy farmers has caused lower prices than the 2014 peaks by more than 10 percent. The drought has accelerated milk cow culling rates and reduced milk output on top of depressed milk prices. Milk production in California has dropped from 2014, whereas national production outside California has remained high. This partly reflects drought, but also the greater reliance of the California dairy industry on exports to Asia, which are depressed as well. We project drought-induced loss in milk production to cause about \$250 million in losses to the dairy industry compared to a normal water year with low milk prices.

The cattle and calf industry depends on pasture (both rain-fed range and irrigated pasture). Lack of rain in early 2015 caused cow and calf numbers to be lower than normal and the shift away from irrigated pasture will decrease forage for feeder cattle. Pasture conditions varied widely with some pasture receiving normal precipitation and others very little precipitation and thus little forage. According to USDA more than three quarters of cattle in California are in areas with exceptional drought in 2015. The low forage per acre again in 2015 has caused continued low stocking rates. Irrigated

pasture acreage also fell as deliveries were cut and water diverted to tree, vine, and vegetable crops.

The California feedlot industry relies primarily on grain from the Midwest, which is not influenced by the drought. But, California feedlots fatten beef calves and dairy steers from California, so will again have a lower supply of cattle. Overall, we expect losses in 2015 to be about \$100 million.

Other livestock industries, which, measured by value of output is primarily poultry and eggs, will be minimally affected by the drought because most of their feed is shipped into California.

Prospects for livestock and dairies for 2016 and 2017 under drought

A continued drought would mean continued higher forage prices than normal relative to milk and cattle prices. The result for the dairy industry would be continued pressure to reduce cow numbers and some further shift back to alfalfa hay, which can be shipped in from other regions relative to silage, which is grown very near where it is used. The result may also be lower milk production per cow.

Continued drought would cause further deterioration of pasture conditions, which means further declines in the cattle herd in California. In addition, with smaller irrigation water deliveries, irrigated pasture acreage may be eliminated in many areas as any remaining water is diverted to trees, vines, and vegetables or high quality silage and hay. Irrigated pasture would remain in areas where water transfers were not feasible. For this analysis we estimate the cost of drought to livestock and dairies in 2016 and 2017 is the same as 2015.

Statewide Economic Impacts of Drought

The direct costs of drought are threefold: revenue losses to crop farming estimated in SWAP, estimated revenue losses in dairies and livestock, and increased pumping costs. We use the IMPLAN model to estimate the corresponding statewide economic drought impacts. Economic impacts include direct, indirect, and induced effects. Direct effects correspond to the estimated direct costs from crop revenue losses, dairies and livestock revenue losses, and increased pumping costs. The indirect effects occur when those parts of agriculture directly affected by drought reduce purchases of inputs from other indirectly affected sectors such as fertilizers, agrochemicals, and farm services. The induced effects account for the overall changes in household income due to the drought. The sum of direct, indirect, and induced effects is known as the total or multiplier effect. For simplicity, only direct and total effects are reported in terms of total sector output (sales), value added (sales minus non-labor business expenses), and employment (seasonal jobs).

Statewide Economic Impacts

Table 4 summarizes our estimated statewide economic impacts of drought on employment, value added, and sector output. Direct costs for 2015 include \$902 million in gross crop revenue losses, \$250 million for dairies, and \$100 million for other

livestock. When we include the farm income losses due to increased pumping costs (\$587 million) and multiplier effects, the statewide impact to agriculture and related industries is \$2.74 billion. Direct job losses in agriculture are estimated to be nearly 10,100 seasonal jobs.

We estimate that total job losses due to the drought are close to 21,000 jobs statewide. These job loss estimates do not include estimates of changes in labor intensity (hours of work per job) or other non-agricultural impacts of the drought. Losses in value added, a measure of the California's Gross Domestic Product (GDP), are estimated to equal \$1.3 billion for the 2015 drought. We estimate the corresponding decrease in statewide labor income, which includes salaries and proprietor income, of \$720 million.

Table 4. Estimated Regional Agriculture Economic Impacts due to Drought, 2015.

2015			
Impact	Jobs (seasonal)	Value Added (\$ millions)	Sector Output (\$ millions)
Direct	-10,100	-400	-1,300
Total	-21,000	-1,300	-2,700
2016			
Impact	Jobs	Value Added	Sector Output
Direct	-10,200	-400	-1,300
Total	-21,400	-1,300	-2,800
2017			
Impact	Jobs	Value Added	Sector Output
Direct	-10,300	-400	-1,300
Total	-21,700	-1,400	-2,900

Economic Impact Summary

We estimate that the 2015 drought may result in 540,000 acres fallow, costing \$900 million in gross crop revenue losses, and 10,100 direct seasonal job losses. Figure 2 illustrates our estimated cropland fallowing, crop revenue losses, and employment losses during the 2015 drought by region. Total impacts accounting for the spillover effects are \$2.7 billion in sector economic impact and 21,000 total jobs.

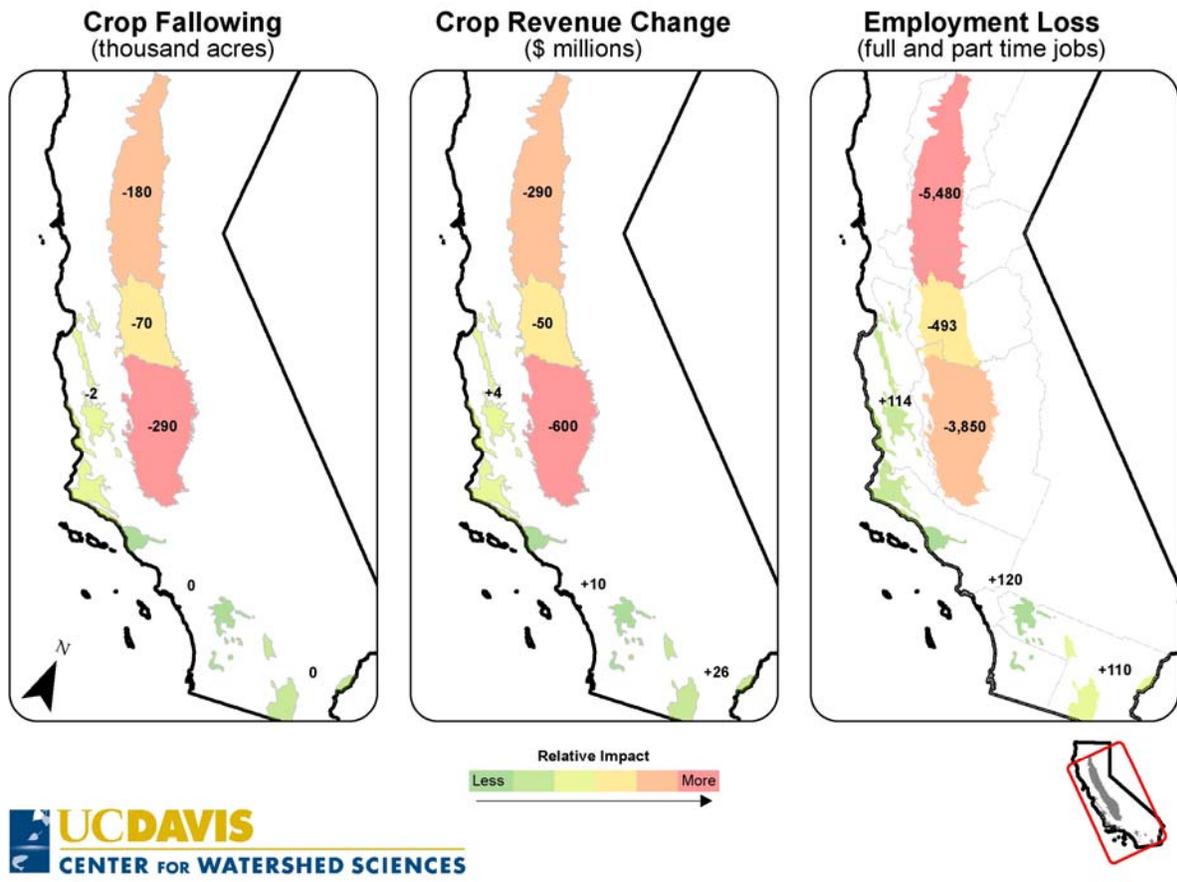


Figure 2. Estimated impacts of the 2015 California drought on crop following, revenues and employment.

Comparisons with the 2014 drought

Some comparisons with the 2014 drought estimates can be calculated in terms of irrigated areas, and direct employment. Appendix C provides estimates of land idling based on remotely sensed information. Appendix D provides a more in depth analysis of agricultural employment in the past years with emphasis on 2014. A summary is presented below.

Irrigated Areas

This analysis compares the economic impacts to California’s agriculture of the 2015 drought to an average water supply year. These show that the 2015 drought is worse than the 2014 drought in terms of surface water shortage to agriculture. We estimate that agricultural surface water allocations will be 25% lower in 2015 than in 2014. Net water shortage to agriculture, after additional groundwater pumping, in 2015 is nearly 67 percent, or 1 million acre-feet, more than in 2014. Cropland following due to drought has increased by 33 percent over 2014. The impact on direct farm-gate revenues is

expected to decrease by a further 6 percent. Groundwater pumping costs are expected to increase by a further 31 percent compared to 2014, due to increased pumping volumes and increased unit pumping costs as groundwater tables decline.

The ability of California's agriculture to adjust to drought conditions is driven by several factors. Increased groundwater pumping is the largest response to drought, as with most drought years, reducing the overall water shortage by over 70%. Regional crop shifting in 2014 was significant. For example, processing tomato contracts shifted to the Sacramento Valley resulting in a small net increase in the statewide tomato harvest, given strong yields in 2014. Water market transfers are also an important adjustment to drought and relieved some of the impact on perennial crops throughout the Central Valley. Early reports this year show some transfers from senior water right holders to east-side perennial crop producers. In addition, our survey of water districts suggests that there will be more transfer of groundwater within districts than in 2014. Taken together, these adjustments blunt much of the economic costs of drought to the agricultural community and food consumers.

Livestock and Dairies

Milk prices are much lower in 2015 than 2014. Losses in production due to the drought are similar in percentage terms to 2014, but with low milk prices the dollar loss is smaller. Cattle and beef prices remain high in 2015 by historical standards, but this is unrelated to the California drought. Losses are similar to 2014 relative to a normal year with high cattle prices.

Employment

The 2014 analysis of the California drought (Howitt et al. 2014) projected a loss of 17,100 jobs in California due to the drought, with about 7,500 jobs lost in agriculture directly. Aggregate agricultural employment statistics for 2014 from the State of California Employment Development Department (EDD) show an overall increase in agricultural employment for California in 2014. While this information seems to contradict the projected job losses, agriculture in California has shown an expansion both in value and in labor over the past years. Using a finer resolution employment database provided by the California Employment and Development Department, several facts can be noticed. First, most of the employment growth for 2014 occurred during the non-irrigation season and in many cases in areas out of the Central Valley such as the Central Coast. Second, a decline in the year to year growth rate of agricultural employment occurred in 2014. It went down from 15,000 jobs from 2012 to 2013, down to 117 jobs during the irrigation season. Third, contract labor including farm management seems to be the most affected during the 2014 drought. A more detailed analysis is provided in Appendix D of this report.

Policy Implications

The severity and adjustments required by the current long-term drought suggest several areas where public policy could be improved.

1. *Groundwater management.* Given the unprecedented rate of groundwater depletion during the current drought, the present 27 year timeline for stabilizing critical groundwater basins under Sustainable Groundwater Management Act (SGMA) of 2014 is likely to be too long to ensure replacement of the cumulated overdraft under the current drought (approximately 15 million acre-feet so far). Groundwater increasingly has a critical role in future agricultural business prospects, particularly with shifts to more permanent and high-valued crops, and will bring pressure to speed the implementation of SGMA.

2. *Data.* Assembling a data-based report, such as this one, on water use and drought impacts highlights the lack of up-to-date and consistent statewide data on water and land use. Given advances in the analysis of remotely sensed data to estimate both water and land use, developed and implemented in states such as Idaho, an investment in similar information systems for California's water managers would be a valuable step forward for many management and policy purposes.

3. *Water Market Transfers.* Both intra- and inter-district water transfers and sales between farmers and other users are flexible and equitable adjustment mechanisms for drought conditions. Our survey of irrigation districts suggests that intra-district markets for water between individual growers are flourishing, and press reports on water sales suggest that sales are occurring at very high prices. In particular, the initiative taken by some water districts to use the existing surface water distribution network to facilitate trading groundwater between district members is a valuable innovation. Transfers will become more important if the drought continues. However, markets require information on market clearing prices and quantities at any given time, to ensure a more equitable and efficient exchange of scarce water resources. A central clearinghouse of information on the quantities being traded, such as an eBay for water or a "Water ISO" (similar to California's electrical energy market) would provide this service to buyers and sellers. Of course, it is essential that these systems do not attempt to set prices, but they must also operate within restrictions on transfer capacity and defined environmental constraints.

4. *Rural Domestic Supplies.* The analysis of predicted changes in groundwater elevation due to current rates of overdraft shows that in many areas of the Central Valley, rural domestic and community water supplies that rely on shallow wells are threatened. In the 2014 drought, several rural communities and many individuals suffered from rapid and unexpected cuts in water supply. Public policy response in the form of emergency support for such communities has improved significantly, and the recent publication of well logs will allow better prediction of areas at risk for domestic supply interruption.

5. *Water Temperature Requirements and Curtailments.* High temperatures in the Sacramento River led to significant loss of salmon in 2014, causing the State Water Resources Control Board to promulgate potential curtailments of Sacramento River releases in 2015. Careful analysis of the likely curtailment levels and the irrigation needs of crops at the end the season show that, in 2015, these curtailments are unlikely to have a large direct impact on agricultural production in the region. If the drought continues through 2016 and 2017 these curtailments could significantly reduce in the ability to divert water from Sacramento River and significantly reduce agricultural production in these regions under continuing drought conditions.

6. *Conservation Trades in the Delta.* In May of 2015 a group of senior riparian Delta water users reached an agreement with the State Water Resources Control Board to reduce their water diversions by 25% from 2013 levels, in exchange for assurance that their riparian rights would not be further curtailed from June through September 2015. This negotiated hedging of water use provided greater economic security for the water users while reducing water diversions overall. While it remains too early to assess the water made available by these actions, this program is a fine example of innovative and equitable institutional changes which allow for both more flexibility and increased predictability in drought response, with a likely reduction in overall environmental and economic risk. This principle of trading risk and uncertainty for use reduction could be applied in other situations.

7. *Agricultural losses from environmental flows.* Environmental restrictions for fish have had some effects on agricultural production, but are generally less than might be expected (Mount and Hanak 2015). Outflows from the Delta for endangered species have only modestly reduced water availability, and farmers seem likely to be able to work around some of the abrupt water losses due to Shasta Dam outflow restrictions needed to preserve cold water for winter-run salmon. There may be long-term water shortage impacts from the endangerment of additional native species due to this drought and greater agricultural losses with more prolonged drought.

8. *Local and regional employment impacts.* The employment impacts of the drought in agriculture are mostly in the Tulare basin, where water scarcity and land fallowing are greatest. These impacts are buffered locally and statewide by continued shifting of agricultural land to higher valued crops which generate more employment per acre. Nevertheless, the employment impacts of the drought can be locally severe, and public action to relieve these pockets of unemployment should be implemented.

Limitations and Extensions

1. *Estimates of water availability.* Our estimates of the reductions in surface water allocations for the 2015 drought seem relatively accurate and well-corroborated. However, the net effect of surface cuts on overall water supply depends heavily on the ability of water users to increase groundwater pumping. Clearly groundwater extraction

is limited by installed pumping capacity, and the rates of flow and elevations in aquifers. We base our maximum pumping capacity in each region on the highest estimate of groundwater extraction by the California Department of Water Resources between the years of 2006 and 2010. This basic data level is modified by two conflicting changes. First, the reduction in elevation of groundwater increases pumping costs, lowers flows, and, in some cases, dries up wells. A second counter effect is the installation of new wells which tend to be larger and deeper. Currently there is no quantitative information on expansion of pumping capacity due to new wells. This is despite the widely agreed fact that there is difficulty getting new wells drilled because of high current demand for well drilling.

2. *Changes in crop demands and agricultural sector growth.* A study that attempts to measure incremental losses from drought must isolate the effect of changing demands and prices for agricultural products from those caused by drought. Over the past four years California crops have been facing very strong demand shifts and increasing prices in real terms. These strong market conditions have induced expansion in some crops, especially nut crops. This crop expansion confuses the impact of drought, both on farm profits and labor employment, if it is measured solely by gross output statistics (Medellin et al 2015b). Our approach of driving the impacts directly from changes in the effective water supply mostly isolates these market forces and focuses on drought related impacts.

3. *Multiplier analysis limitations.* Impact analysis using models like IMPLAN have some inherent limitations including fixed prices and lack of flexibility in production factor use. In reality prices change in response to market conditions and economic events if the impacts are large enough. Furthermore, intensity of production factors in agriculture such as labor, water and agrochemicals can be also adjusted in response to external events such as drought. Whereas some of this is captured by the SWAP model, input-output models like IMPLAN assume fixed proportions which can be especially important for labor impact estimation. Thus input-output models tend to underestimate the ability of the regional economy to accommodate labor and other factor use among sectors.

4. *Downstream impacts on California's economy.* The focus of this report is on agricultural production including crops, livestock and dairies. These three sectors and farm services (mostly contract labor) altogether represent a relatively small proportion of California's state economy. However products from agriculture serve as production inputs for much larger value added sectors like food processing which have a higher share in the economy.

5. *Remote sensing.* While there is good confidence in the precision of our water supply driven crop model analysis and the resulting economic impacts, it is useful to cross-check results for consistency with information on cropping from USDA surveys and remotely sensed measures. We note that USDA and remote sensing generate information on total land idling, which is different than land fallowing due to drought. The USDA NAAS surveys farmers on their cropping intentions for fodder and field crops. Given the highly heterogeneous pattern of California crop production, the survey

is subject to sample size limits and response bias. A second comparison uses remotely sensed measures of greenness of fields to compare the total area of idle land with that in a normal base year of 2011. NASA preliminary estimates for this year range from 580 to 730 thousand acres idled in the Central Valley SWAP regions with a confidence of 95%. The research team of this report also conducted an assessment using the green normalized vegetation index scored for wet fields. Results from this approach indicate an increase in idle land with respect to last year in the order of 60 thousand acres. A detailed discussion of these two alternative crop data sets is found in Appendices C and D of this report.

Conclusions

Several conclusions arise from this and the 2014 analysis:

1. Surface water shortages of nearly 8.7 million acre-feet will be mostly offset by increased groundwater pumping of 6 million acre-feet. Groundwater offsets almost 70% of the drought surface water shortage. Most of water shortages will be in the Central Valley.
2. Net water shortage of 2.7 million acre-feet will cause 540,000 acres to be fallowed in 2015, 114,000 acres more than in 2014. Most fallowed land is in the Tulare Basin.
3. The direct costs of drought to agriculture will be \$1.84 billion for 2015, and 10,100 direct seasonal jobs. When multiplier effects are considered, the total economic sector impact will be as high as \$2.74 billion and potentially 21,000 jobs statewide.
4. The effects of continued drought through 2017 based on continued 2015 water supplies may be 6% worse than 2015, with net water shortage increasing to 2.9 million acre-feet per year. Gradual loss of groundwater pumping capacity and water elevations will add to the incremental costs of a prolonged drought.
5. Increased groundwater overdraft during drought will slowly deplete groundwater reserves at an incremental cost. New groundwater regulations could eventually reverse this trend and force groundwater basins towards sustainable yields, at the expense of some increased fallowing or longer crop rotations by preserving California's ability to support more profitable permanent and vegetable crops through drought.

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