Appendix A: Water Availability Assessment

Jennifer Scheer and Kabir Tumber

Our team surveyed over 80 irrigation districts, mostly through personal interviews, during the spring and the mid-summer of 2015 to assess the water supply outlook for agricultural irrigation. We asked district managers about the following topics:

1. Estimated fallowing in 2014
2. Expected fallowing in 2015
3. Increases in irrigation water charges (fixed and volumetric)
4. Dry wells and whether these were domestic, municipal, industrial (M&I) or agricultural
5. Groundwater substitution, on-farm and within the district
6. Transfers in and out of the district: volume, price, and import/export region

Many irrigation districts reported that groundwater substitution and water transfers ameliorated some of the 2014 drought impacts. In addition, surface storage, banking, and within-district transfers were used extensively. Most districts reported that some domestic and M&I wells went dry, but few agricultural wells went dry because they are typically drilled deeper than domestic wells, and far below existing groundwater elevations. Most districts confirmed new, deeper wells are currently being drilled at a rapid pace.

Water rates in most of the districts we surveyed did not increase significantly during 2015. At the extremes, one district reported lowering rates from 2014 to 2015 and one district increased rates by over 75%. Most rate increases were in the range of 3-10%, reflecting normal growth in rates rather than a response to the drought.

Most districts reported uncertainty about 2015 fallowing. Many districts are delivering smaller allotments of water to growers, with deliveries ranging from one-tenth of an inch to 36 inches per acre, typically less than normal crop irrigation water use. Other districts are delivering no water to growers but are allowing growers to wheel groundwater through their system for a fee. Growers with private wells can also transfer water to other growers within these districts. Many growers have standby wells for early and late season irrigations and to increase irrigation scheduling flexibility. Growers with standby wells can use them to move water through the system (if the district permits it), supplement reduced district deliveries, or depending on the size of their standby wells, run the wells to fully irrigate their crops. In most areas the energy cost to the grower to lift and pressurize groundwater is significantly more expensive than district surface water. Groundwater substitution allows growers to avoid fallowing land, but the higher pumping cost reduces profits and is an important economic cost.

Water transfer volumes vary significantly between districts. The average price across all of the districts surveyed was reported to be $650 per acre-foot. Sacramento River settlement contractors were perhaps the most active in water market transfers this year, sending water to Sacramento River service contractors with zero allocation and to users south of the Sacramento-San Joaquin Delta. Feather River contractors with senior water rights initially planned to transfer water south of the Delta, however a reduced allocation of 75 percent caused most districts to rescind the transfer. Early in the irrigation season San Joaquin River Exchange Contractors agreed to transfer water to Friant Canal users, effectively increasing Friant surface water deliveries from 0 to about 5 percent. Due to late season rains in the Sierra Nevada the Exchange Contractors are now receiving additional water supplies from Millerton Lake.

Even this late in the irrigation season water supplies are still uncertain in some areas. Sacramento River contractors have faced challenges in both water availability and timing due to operational restrictions on Shasta Reservoir implemented to maintain sufficiently cool temperatures for winter-run salmon. The change came after cropping decisions were made and fields were planted for the year, leaving farmers and irrigation districts scrambling to fill the gap in supply with groundwater. With releases limited for Shasta Reservoir, system operators depend more on Lake Oroville for fresh water releases to manage salinity in the Sacramento-San Joaquin Delta. Feather River contractors surveyed expressed some concern about the Department of Water Resources' ability to deliver their allocations.

On May 22, 2015, the State Water Resources Control Board approved a program for Sacramento-San Joaquin Delta riparian water right holders to voluntarily reduce water consumption by 25% compared to 2013 levels. In exchange, participating water users received assurance that their riparian rights would not be further curtailed from June through September 2015. Participating growers can achieve the 25% reduction in water use through fallowing, reduced diversions, or a combination of approaches. The State Water Board has said it will enforce the program by conducting spot checks throughout the irrigation season. Growers who elected to enroll in the program were required to submit an application by June 1 and to provide information regarding their water rights, acreage and crops farmed, and their plan to reduce water use.

Appendix B: USDA Acreage Projections

Jennifer Scheer, Duncan MacEwan, and Richard E. Howitt

The USDA surveys growers annually before the planting season (Prospective Plantings Survey), in the middle of the growing season (June Plantings Survey), and after the growing season. The USDA survey primarily covers commodity crops and does not include the specialty crops that make up much of California agriculture. The CDFA and specialty crop producer associations, such as the California Almond Board and the California Avocado Commission, also survey producers and generate their own annual planted acreage reports. We use these surveys to supplement the remote sensing analysis and as a useful cross-check of the SWAP model estimates, with some important caveats.

Crop surveys estimate the acreage planted for major crops in California on a state or county-wide basis. By comparing acreage across years we can estimate the change in total irrigated area for these major crops. The change in irrigated acreage between years is driven by several factors and consequently does not represent only the effects of drought. An observed decrease in acreage for a specific crop during drought years might not be a result of the drought. Crop prices, disease, shifts to perennial crops, and other market conditions are just some of the other factors that also may affect planting decisions. Our modeling approach using the SWAP model controls for these other factors to isolate the effect of drought. That is, the crop acreage estimates in annual surveys should not match up with the drought impacts estimated by the SWAP model, and are only useful as a cursory cross-check of broader trends in crop acreage.

We compared the changes in acreage due to drought and the USDA planting surveys. The SWAP model land use data are from the California DWR and use different crop definitions than the USDA, CDFA, and other surveys. In fact, and this may come as a surprise to the reader, California does not have a consistent statewide crop acreage dataset. The estimated irrigated area by crop differs between USDA, remote sensing, County Crop Reports, DWR, and GIS surveys, to name a few. We do not attempt to reconcile these differences here, but rather point them out so that the reader understands the USDA surveys and DWR data in SWAP have different baselines. In particular, for commodity crops reported by USDA the irrigated area in SWAP can be as much as +12% or -10% of the area estimated by USDA. In total, the irrigated area in SWAP (DWR data) is 2.6% less than the USDA numbers for these crops.

Our analysis finds that our drought fallowing estimates using the SWAP model are consistent with the USDA planting surveys having taken account for the effects of water transfers and crop shifting.

Appendix C: Remote Sensing Analysis of Fallowing

Quinn Hart, Nadya Alexander-Sánchez, Forrest Melton, Josué Medellín-Azuara and Andrew Bell

In addition to USDA statistical information, remotely-sensed data was employed to estimate idle land in agricultural during 2011, 2014 and 2015. Multispectral satellite imagery from Lansdsat 7 and 8 was used covering the Central Valley during the irrigation season. Several methods were considered to estimate idle land mostly involving normalized difference indexes. Furthermore, idle land estimates of summer idle land for 2011, 2014 and 2015 were provided by a research team from the NASA Ames Research Center as part of an ongoing research effort in collaboration among NASA-ARC, DWR, USDA and the USGS. Estimates from both UC Davis and the NASA-ARC lab show an increase in summer idle land in 2015 with respect to both 2011 and 2014 (Table C-1). A brief description of the methods and the preliminary results is provided below.

Remote sensing estimates of idle land do not necessarily indicate drought-related crop fallowing. Idling land in agriculture may be the result of yield-related rotations and other farm practices. For 2011, a year with higher than normal precipitation, NASA-ARC estimates 1.2 million acres idled in the SWAP central valley coverage area (about 6.7 million acres in NASA-ARC land layer). In addition to water availability, market conditions and other factors highly influence California's agricultural landscape.

NASA Ames Research Center Estimates

NASA-ARC employed time series of Normalized Difference Vegetative Index (NDVI) data from various satellites including Terra, Aqua, Landsat 5, Landsat 7 and Landsat 8 to create 8-day composites to generate winter and summer idle crop land estimates. Overall accuracy is 95% based on comparisons with 670 field validation sites.

For summer fallowing in the 2014 drought, estimates indicate 525,600 acres for all land use categories (470,450 for SWAP crop groups). For 2015, NASA-ARC estimates an increase in fallowing for all land use classes up to 670,000 until by end of July with bounds of 585,500 and 726,700 acres and a 95% confidence level. Updates of these estimates will be available as the irrigation season closes.

UC Davis idle land estimates based on remote sensing

A remote sensing and GIS based methodology was developed to obtain an initial estimate and a trend for idled land for California's central valley between 2014 and 2015. The approach will at this point will only indicate whether there is a trend in idle land between the two years. Further refinement of the method will provide acre-estimates of idle land. Data products employed in the estimation include:

- Landsat 8 - Landsat imagery for the years 2014 and 2015, between 6/1 and 8/1 were used to estimate cultivation in the valley
- USDA Cropland Database - Years 2013 and 2014 were used to estimate the areas under cultivation for rice and cotton crops.
- CA's DWR Landuse - These maps delineate Agricultural fields, and was used to determine what areas in the central valley are farmed.

Using the Landsat imagery, two indices were calculated for every cloud free pixel over every image in time intervals described above. A Green Vegetation index (NIR/Green - 1) (GCVI) and the Normalized Difference Water Index (NDWI). For each scene, the higher of the two indices was taken as the "cropped" score. NDWI was used for fields like rice that were highly watered late into the season, where they potentially masked the greenness of the crops. At 14 day intervals, the scores were calculated as the average score from the closest cloud free pixel before and after the interval. The final score was the summation of each interval score. Using this method allowed a normalized score, and proper weighting of scenes, even in the presence of intervals with scenes that contained clouded imagery over parts of the valley.

Table C-1: Comparison of idle land estimates

Region	SWAP	NASA-ARC
Sacramento	179,195	206,105
San Joaquin	72,461	108,689
Tulare Lake Basin	287,984	362,486
Central Valley	539,639	677,280

Figure C-1 shows this "cropped" score over all Agricultural lands in the Central Valley. The low end of the score are the idled areas. Since the score changes gradually over the region, determining an exact threshold for idled lands is challenging, and probably varies from crop type to crop type. However, looking at thresholds in the range of 6 to 8 gives a general idea of the total fallowed lands. The higher greener bars indicate increase in this low scores from 2015 over 2014. The approach is to be refined in the following weeks to provide acre estimates of idle land yet indicates increased fallowing between 2014 and 2015 of at least 60,000 acres.

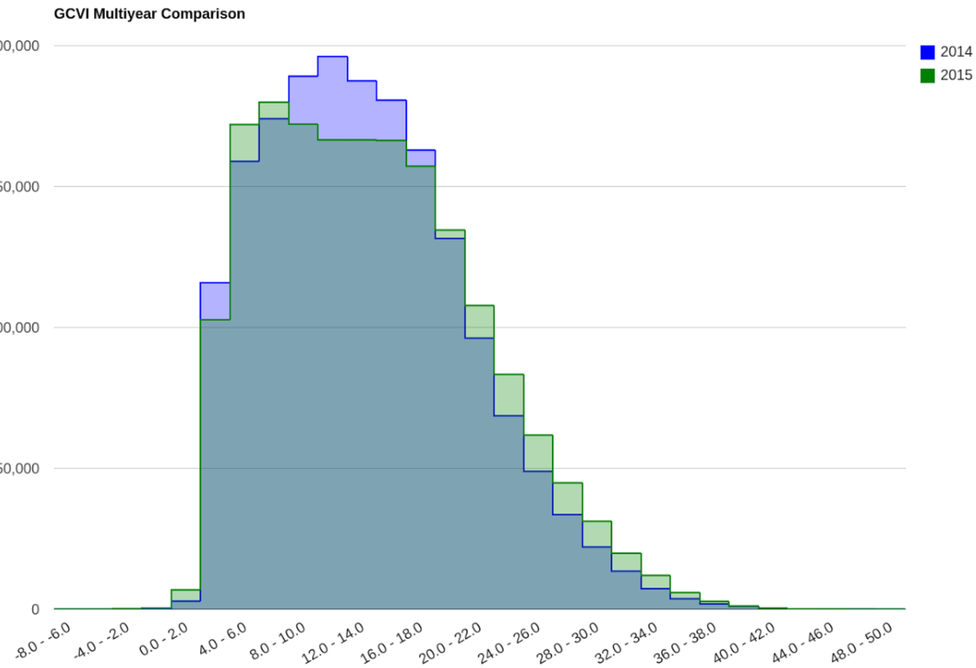

Figure C-1. Comparison of Green Vegetation Index (GVNI) between 2014 and 2015 for all crops.

Appendix D: Agricultural Employment Analysis

Josué Medellín-Azuara, Duncan MacEwan, Richard Howitt, Jay R. Lund

Agricultural employment during drought is a concern particularly for areas in the Central Valley where agriculture is a higher proportion of total employment.

This Appendix reviews farm employment since 2010 at the county level using data from the California Employment and Development Department (EDD)

Drawing inferences and trends from these data is challenging for several reasons:

- The workforce migrates between regions, following schedules for planting, harvesting and other activities in the cycle of farm production
- Commodity prices can override water scarcity and cost in planting decisions
- A high proportion of farmworkers in many places is undocumented and it is estimated that for each full time equivalent job there are two employees.

These challenges merit more in-depth analysis using statistical methods to control for these confounding factors and adjust for undocumented workers.

A preliminary analysis of the raw state agricultural labor data for crop farming, livestock and dairies, and support services for agriculture (e.g. contract labor), shows that during the irrigation season (April to September) there is an increase of roughly 120 jobs statewide from 2013 to 2014, and 8120 during the non-irrigation season. A breakdown by region shows that most of the growth occurred in the less drought-impacted Central Coast region with monthly average 1,850 jobs during the irrigation season and 2,520 jobs during the non-irrigation season.

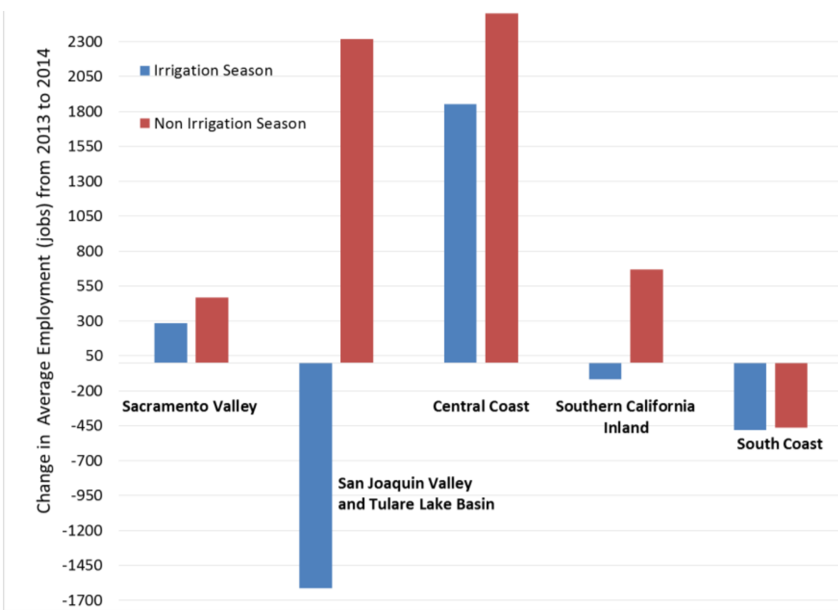

Figure D-1. Changes in average monthly farm employment, 2013-2014. Source: authors calculations using California Employment and Development Department (EDD) data.

In contrast, the San Joaquin Valley shows a decline of 1,620 jobs during the irrigation season and an increase of 2,320 jobs during the non-irrigation season. The South Coast shows average monthly losses of 475 in both seasons and other areas in the state have modest increases in the hundreds. Figure D-1 above shows these findings. Part of the increase in labor can be attributed to a growth in summer farm labor in the Sacramento Valley and coastal regions, which had better water availability, and increasing prices of high-value vegetable and field crops during the 2014 drought.

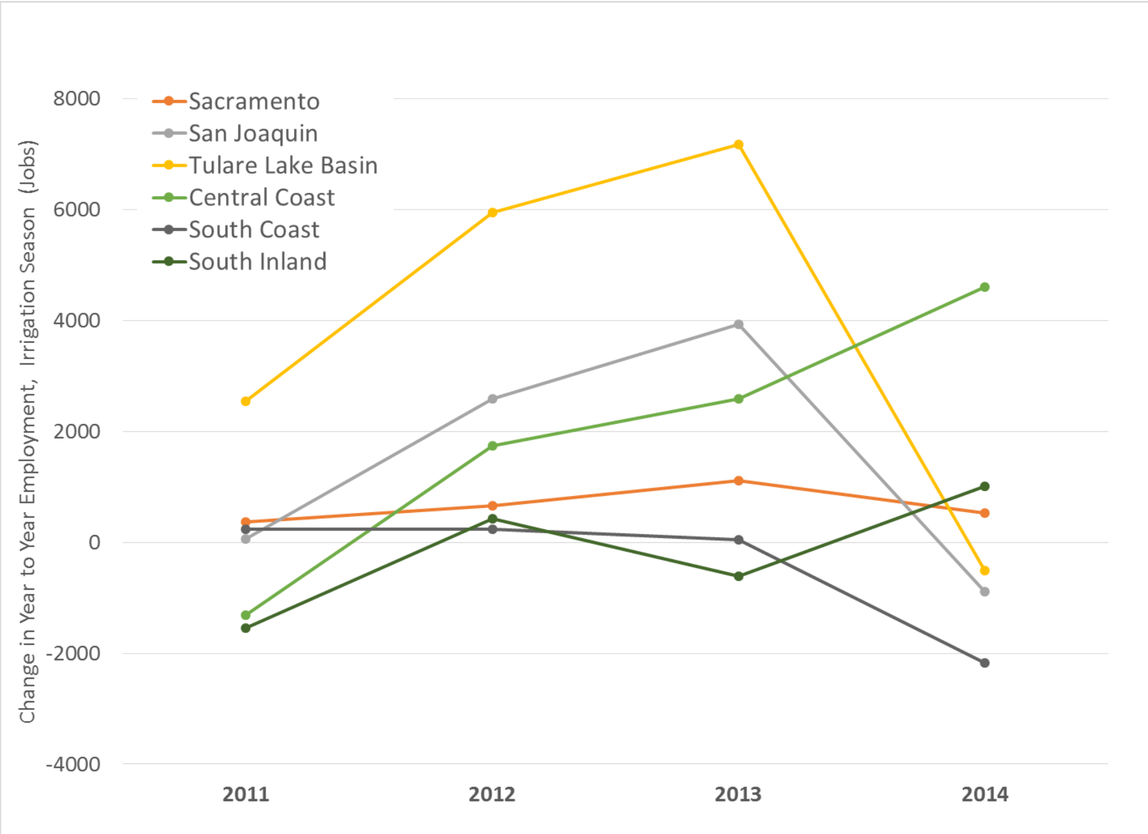

Figure D-2 Year-to-year change in farm employment during irrigation season for selected regions. Source: authors calculations using California Employment and Development Department (EDD) data.

More important, the pattern of agricultural labor is consistent with a longer term trend towards more agricultural employment in California, driven largely by shifts to crops that yield higher revenue per acre and per acre-foot of irrigation water (Medellin et al 2015b). Figure D-2 below shows the discussed decline in year to year employment for all three areas in the Central Valley for the irrigation season. A sharp decline in growth in the Tulare Lake basin could be attributed in part to drought conditions. Figure E-3 below shows quarterly employment from 2010 to 2013 for the Central Valley the coastal areas an inland southern California.

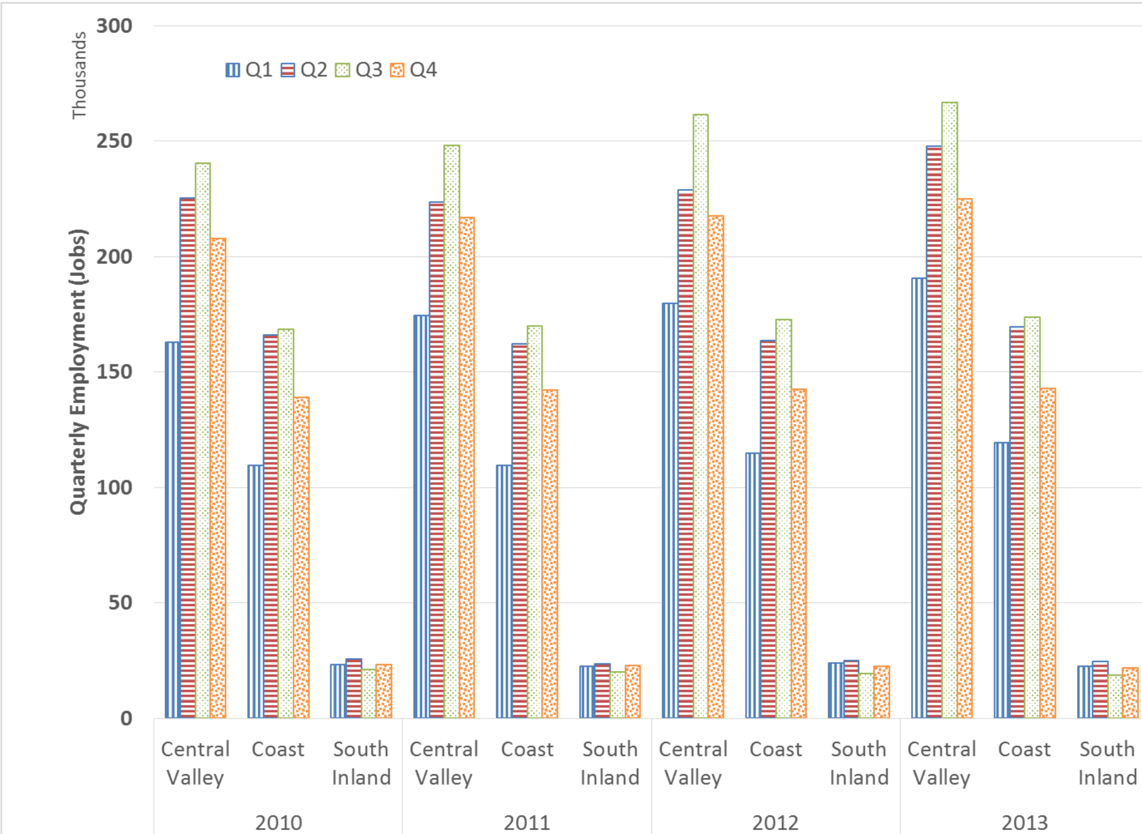

Figure D-3. Quarterly employment by region. Source author calculations using EDD data.

The droughts in 2014 and 2015 are causing land fallowing and significant job losses compared with employment that would have occurred without drought conditions. Global and national market forces and farm adjustments are important for mitigating drought impacts to agriculture and California's economy. Regions with greater surface water shortages and less access to groundwater will suffer larger employment losses due to drought.

Appendix E: Disaggregate Economic Impacts

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

The main report provides estimates of statewide economic impacts. This Appendix gives a breakdown of impacts by region. The regions are: The Sacramento River Basin, Delta and East of Delta, the San Joaquin River Basin south of the Delta, the Tulare Lake Basin, and all other areas. Counties considered in each region are listed in the table below.

Table E-1. Counties included by region for the economic impact analysis

IMPLAN Regions	Counties
Sacramento River	Amador ,Butte , Calaveras, Colusa ,Contra Costa,El Dorado, Glenn , Placer ,Sacramento, Shasta, Solano,Tehama, Sutter, Yolo and Yuba
San Joaquin River	Madera, Mariposa, Merced, San Joaquin, Stanislaus, Tuolumne
Tulare Lake Basin	Fresno, Kings, Tulare, and Kern
Central Coast	Monterrey, Santa Clara, San Benito, San Luis Obispo
South Coast	Ventura, Los Angeles, San Diego, Santa Barbara
Inland Southern California	Imperial and Riverside

The table below provides for the 2015 drought projections on employment, labor income, and value added and sector output. Impacts include crop revenue losses and increased pumping costs. Dairies and livestock impacts are statewide, yet most activities in these sectors occur in the Central Valley.

Employment is reported in seasonal jobs, these account for the empirical estimate of 2 seasonal jobs per full time equivalent following Martin and Taylor (2013). Labor income includes salaries and wages and proprietor income. Value Added measures includes salaries and wages, proprietor income and profit and indirect business taxes. Value added is that portion of value of output contributed by labor and capital within each sector. This is a measure comparable to the gross domestic product in a region, and is the difference between the sector output and the non-labor business expenses also known as inter-sector purchases. In economic contribution studies value added is often a preferred measure of economic value. Sector Output for agriculture corresponds to the farm gate revenues received by farmers. In the case of crop farming and on a per acre basis this is simply the price of the commodity multiplied by the average yield per acre.

The economic impacts of reduced agricultural are generally classified as direct, indirect and induced effects on each of the aggregates just defined.

Direct effects are simply impacts on output, value added, or employment directly within the affected industry. Indirect effects are those changes that occur through purchases of input goods and services from supporting industries. For example, crop agriculture requires purchase of inputs such as agrochemicals, fuels and water. It is assumed that reduced irrigated area will reduce revenues and purchase of inputs is reduced proportionally. In reality, some adjustments occur in terms of input use intensity and prices. Induced effects trace consumption expenditures. These measure the economic impacts in each industry that result from reduced consumption generated by not spending the lost household earning from direct and indirect effects. Total effects are the sum of direct, indirect and induced impacts. We report only direct and total effects.

The sum of impacts in all regions will not match the Central Valley total impacts due to region-varying ratios, multipliers for employment, labor income, value added and sector output. Regions grouped tend to have higher multipliers than smaller areas due to lower economic out-of-region expenses.

Table E-2. Breakdown of economic impact by region and statewide for the 2015 drought.

Impact type	Employment (jobs)	Labor income (dollars in millions)	Value added (dollars in millions)	Output (dollars in millions)
1. Sacramento Valley crops and increased pumping costs				
Direct Effect	-5,473	-45.0	-64.4	-289.0
Total Effect	-7,784	-130.7	-226.6	-574.0
2. San Joaquin Valley crops and increased pumping costs				
Direct Effect	-493	-6.2	-5.7	-48.8
Total Effect	-820	-16.1	-25.4	-82.8
3. Tulare Lake Basin crops and increased pumping costs				
Direct Effect	-3,854	-214.4	-218.4	-604.0
Total Effect	-10,875	-447.6	-626.0	-1,300.0
4. Central Valley crops and increased pumping costs*				
Direct Effect	-9,449	-263.6	-293.2	-941.8
Total Effect	-19,004	-623.6	-1,005.0	-2,082.3
5. Crops in Salinas Valley, inland and coastal Southern California				
Direct Effect	304	15	15	39
Total Effect	575	23	30	61
6. **Statewide livestock and dairies**				
Direct Effect	-978	-36.8	-140.4	-350.0
Total Effect	-2,564	-120.4	-293.4	-721.1
7. Statewide economic impacts				
Direct Effect	-10,122	-285	-418	-1,252
Total Effect	-20,992	-721	-1,269	-2,743

*Direct and total effects from the three Central Valley individual basins may not add up to the Central Valley totals as the region-wide multipliers vary.

Results from this breakdown highlight the relative impact over large regions to adapt to surface water shortage and the labor intensity from revenue losses. The Sacramento Valley for example has higher direct job losses per unit or crop revenue loss, but the Tulare Lake basin has a labor multiplier. On the other hand, modest losses in irrigated land in areas outside the Central Valley do not necessarily result in revenue and job losses, as these regions benefit from slightly higher prices on labor intensive commodities.