Economic Impacts of the 2021 Drought on California Agriculture

Preliminary Report

Prepared for: The California Department of Food and Agriculture

Josué Medellín-Azuara
Alvar Escriva-Bou
John A. Abatzoglou
Joshua H. Viers
Spencer A. Cole
José M. Rodríguez-Flores
Daniel A. Sumner

With Research Support from:

Vicky Espinoza, Humberto Flores-Landeros, Nicholas Santos, Anna Rallings, Sarah Naumes, and Angel Fernández-Bou

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About the Authors

Josué Medellín-Azuara, **Ph.D**., Associate Professor, Civil and Environmental Engineering and Director, Water Systems Management Lab, UC Merced.

Alvar Escriva-Bou, **Ph.D.,** Senior Fellow, Public Policy Institute of California.

John A. Abatzoglou, Ph.D., Associate Professor, Management of Complex Systems, UC Merced.

Joshua H. Viers, Ph.D., Professor, Civil and Environmental Engineering and Director, CITRIS and the Banatao Institute, UC Merced.

Spencer A. Cole, Graduate Student, Environmental Systems Graduate Group, and Water Systems Management Lab, UC Merced.

José M. Rodríguez-Flores, Ph.D., Candidate, Environmental Systems Graduate Group, and Water Systems Management Lab, UC Merced.

Daniel A. Sumner, **Ph.D.,** Frank E. Buck Jr. Distinguished Professor, Agricultural and Resource Economics, UC Davis.

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Executive Summary

The ongoing multi-year drought that began in 2020 had far below average precipitation statewide. As a result, the 2021[1] water year ended up as the second driest two-year period on record. Although precipitation deficits were widespread, drought conditions were more severe in the Sacramento and Northern Coast regions. Few atmospheric rivers and below average snowpack depleted storage in most reservoirs and aquifers during 2021. Yet drought is not only marked by water supply – in this case, warmer temperatures and antecedent dry conditions increased crop evaporative demands, furthering the gap between water supply and crop irrigation demands.

This drought has occurred early in Sustainable Groundwater Management Act (SGMA) implementation, enacted in 2014 to avoid undesirable consequences of unsustainable groundwater use. The implementation of groundwater sustainability plans (GSPs) for critically overdrafted basins began in 2020, while other medium and high priority basins had just submitted their plans earlier this year. Increased demand for groundwater pumping to minimize the impacts from drought surface water shortages contributes to challenges to meeting SGMA mandates.

This report provides preliminary estimates of economic impacts to agriculture for the current drought using a combination of surveys of irrigation districts, a review of hydrological information, and remote sensing data. We cover selected irrigated agricultural areas where drought impacts were more significant during 2021, including the Central Valley, the Russian River basin (North Coast), and northern intermountain valleys in Siskiyou, Shasta and Modoc counties. The drought reduced surface water deliveries during 2021 by 5.5 million acre-feet (maf) compared to predrought conditions. To mitigate these shortages, farms increased groundwater pumping by about 4.2 maf, resulting in a final net shortage of roughly 1.4 maf. This water shortage resulted in 395,100 additional acres of idled cropland, along with some crop yield impacts from reduced water application. Altogether, direct economic costs of drought for agriculture are estimated at $1.2 billion (including $184 million in greater pumping costs), with roughly 8,745 full and part-time job losses (Table ES-1). Considering the effects on other sectors as well, total economic impacts are estimated at $1.7 billion and 14,634 jobs. In comparing to the 2012-16 drought, impacts on idled land and direct crop revenue losses are comparable to 2014 but significantly smaller than those in 2015—the height of the past drought (Table ES-1). However, the spatial distribution of such effects varies, with more impacts through idled land and revenue losses in the Sacramento and North Coast regions.

[1] The 2020-2021 water year runs from October 1, 2020 to September 30, 2021.

Almost all drought-idled land occurred in the Central Valley (roughly 385,000 acres). Several parts of the Sacramento River Basin, the west side of the San Joaquin Valley, Tulare County and some irrigated areas in Kern County were the most affected by increased fallowing compared to pre-drought conditions. Crops with major increased fallowing include rice in the Sacramento Valley, cotton in the San Joaquin Valley, as well as grain and other field crops statewide. Drought-related increase in pumping in the San Joaquin Valley was less extreme than a comparable point in the 2012–2016 drought. Water cutbacks in the Russian River basin during this past year reduced local grape crop yields, without significant reduction in irrigated agricultural areas. Rainfed feed crops and pastures suffered sizable losses that affected some organic dairy farms. Some limited, late-season water cutbacks in northern intermountain valleys reduced yields in forage crops and increased idled land. In the dairy sector, higher milk prices—caused by global demand—raised overall revenues and reduced drought-related effects of higher production costs. The beef cattle sector had to adapt to scarce winter pasture and higher forage prices. However, California's beef cow herd increased in size and as a share of the national cow herd, leading to potential revenue gains.

Table ES-1. Summary of Preliminary Annual Economic Impacts of the 2021 Drought on Agriculture in the Central Valley, the Russian River Basin and Northern Intermountain Valleys.

Description	**Current drought**	**2012-16 drought***	
	2021	**2014**	**2015**
Surface water shortage (maf/year)	5.5	6.6	8.7
Groundwater replacement (maf/yr)	4.2	5.1	6
Net Water Shortage (maf/yr)	1.4	1.5	2.7
Drought-related idled land (acres/yr)	395,100	428,000	540,000
Crop Revenue Losses ($ million/yr)	$962	$876	$973
Increased Pumping Costs ($ million/yr)	$184	$491	$638
Direct Economic Costs ($ million/yr)	$1,146	$1,586	$1,989
Direct Employment Losses (jobs/yr)	8,745	6,920	10,000
Total Economic Impacts ($ million/yr)	$1,705	$2,372	$2,919
Total Employment Impacts (jobs/yr)	14,364	15,480	21,700

*Inflation adjusted. Adapted from Medellín-Azuara et al. (2015), Howitt et al. (2015) and Lund et al. (2018). Agricultural area coverage out of Central Valley differs between the current and the 2012-2016 studies.

Some elements of this assessment merit refinement, including establishing an appropriate pre-drought baseline (as some crops have been experiencing long-term changes in irrigated area), and the assessment of drought-related idled land, cutbacks, and crop yields. Additionally, distinguishing commodity market factors in planting decisions from water cutbacks may reduce some uncertainties. Nevertheless, our preliminary estimates provide a clear picture of the impacts of the 2021 drought in California's agriculture are a foundational exploration of such uncertainties to improve retrospective and predictive analyses of droughts and California's Agriculture.

Introduction

While the 2021 water year was very dry throughout California, it was even drier in the northern part of the state, which had not experienced such severe drought for many decades. Additionally, this ongoing drought is occurring in the early implementation of local groundwater sustainability plans (GSP) required by the 2014 California Sustainable Groundwater Water Management Act (SGMA).

This report provides preliminary estimates of the economic impact of the recent drought on agricultural systems, and the regional economies in California's Central Valley (Sacramento, San Joaquin, and Tulare Lake Basins), the Russian River Basin and selected northern intermountain valley regions within Lassen, Modoc, Shasta and Siskiyou Counties (Figure 1). We employed a variety of data sources and economic models to estimate surface water shortages and access to groundwater. We estimated patterns of land idling for different crops in response to the drought conditions.

In the following sections, we provide brief overviews of climatic conditions and California agriculture, 2021 water supply shortages, preliminary economic impacts on crops and livestock, and in the regional economies of the studied areas. The report closes with 2021 drought takeaways and insights on adaptation to ongoing and future droughts.

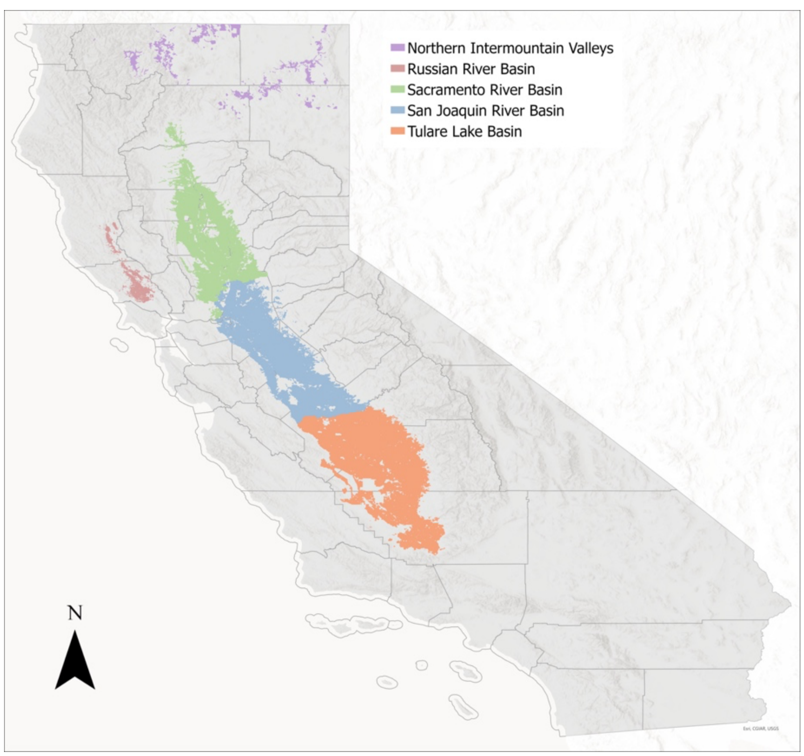

FIGURE 1. AGRICULTURAL REGIONS COVERED IN DROUGHT IMPACT ASSESSMENT.

Climate Synopsis

The consecutive hot-dry water years of 2020 and 2021 culminated in extreme drought for much of California by summer of 2021. Signs of drought included low spring snowpack, subpar precipitation, low streamflow, and well above normal temperature and evaporative demand. The 2021 water year ended with the 3rd lowest precipitation statewide (50% of 20th century average) and 2nd warmest (3.5°F above 20th century average), since 1895. The combined 2020-2021 water years had the 2nd lowest precipitation on record, only slightly higher than that of 1976-77. However, temperatures during 2020-2021 were 3°F warmer than during the 1976-77 drought.

A northward shift in the winter storm track and a limited number of landfalling atmospheric rivers in California left the state parched and contributed to deepening water deficits. Precipitation deficits were also reflected in a 60% of average late winter snowpack, rapidly lost to warm temperatures, parched soils, and dry conditions. Record low April–August precipitation was seen for much of the western slopes of the Sierra Nevada northward into the Klamath basin, exacerbating vegetation drought stress. Cumulative precipitation deficits during October 2019-September 2021 left much of northern California missing more than a year's worth of precipitation and contributed to low and record-low reservoir levels by the end of summer 2021.

Notably, drought is not solely defined by lack of water supply, but also includes changes in demand. Water demand is driven by a host of processes including irrigation practices. Increased evaporative demand exacerbated the magnitude of recent droughts, including the ongoing one. Evaporative demand during April-October 2021 was the highest since 1895 and four inches more than the late 20th century average. This exceptional atmospheric thirst has further taxed sparse soil and vegetative moisture, accelerating drought conditions.

The Palmer Drought Severity Index (PDSI), which normalizes soil moisture anomalies based on precipitation and evaporative demand, shows extreme low values (below –4 index values) in September 2021 (Figure 2a). PDSI values in the Sacramento basin were the lowest since at least 1895—topping individual values during the 2012–2016 drought. In contrast, PDSI values in 2021 were not as extreme in the San Joaquin and Tulare Basins relative to that drought. Figure 2a also confirms drought intensity shifted to the North Coast and the Sacramento River watersheds, typically water rich compared to the 2012–2016 drought, in which the epicenter of dryness occurred in the San Joaquin Valley (Escriva-Bou et al. 2021). Contextualizing supply and demand gaps, water year 2021 had the lowest precipitation and highest evaporative demand (Figure 2b) compared to the 1979–2021 period, with water year 2020 close behind.

A hallmark of recent droughts, including the 2012–2016 drought, is the acute atmospheric thirst tied to increasing atmospheric temperature and evaporative demand. This increased atmospheric thirst not only depletes soil and vegetative moisture in natural lands, but it can also translate into heightened irrigation demands for agricultural lands. Secondarily, these trends also result in indirect impacts to agriculture through poor air quality affecting farmworker health and quality of products induced by widespread and persistent wildfires.

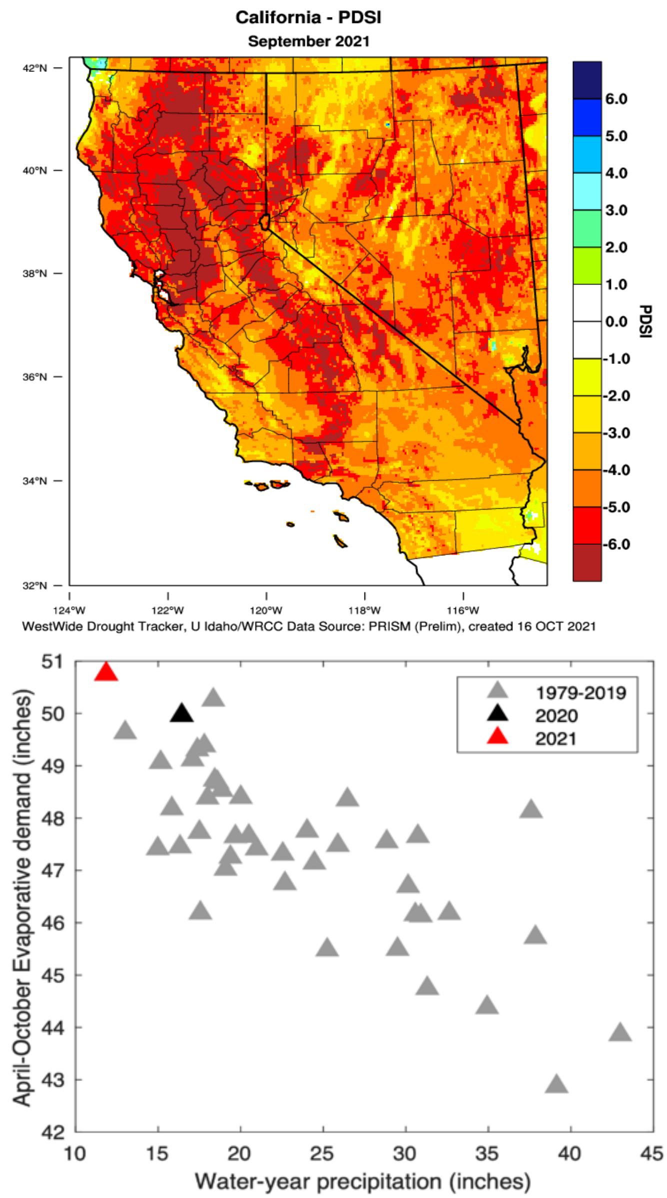

FIGURE 2. (A) PALMER DROUGHT SEVERITY INDEX (PDSI) FOR SEPTEMBER 2021 FROM THE WEST WIDE DROUGHT TRACKER (HTTPS://WRCC.DRI.EDU/WWDT/). (B) SCATTERPLOT OF WATER YEAR PRECIPITATION AND APRIL-OCTOBER EVAPORATIVE DEMAND FOR CALIFORNIA DURING 1979–2021.

Agriculture Overview

California agriculture ranks first in the nation in size and value. Cash receipts averaged $50 billion from 2018 through 2020 (USDA-ERS 2022). In 2020, milk remained the top commodity in value ($7 billion) followed by almonds ($5.8 billion) and grapes ($5.5 billion) according to the Farm Income and Wealth Statistics, Cash Receipts by State (USDA-ERS 2022). The leading counties in agricultural revenue were Fresno, Kern and Tulare in the southern San Joaquin Valley. Together, these counties produce about 36% of the state's value of agricultural output including a considerable share of the three major commodities of milk, almonds and grapes (USDA-ERS, 2022).

A substantial increase in the irrigated areas of permanent crops, berries and other high revenue per acre specialty crops has contributed to growth in revenue per unit of land and water used (Sumner, et al, 2021a). Many leading crops have kept relatively constant acreage in the last decade, but falling acreage of wheat, alfalfa and cotton has made room for the growth in the major tree nuts. Rice and cotton areas are particularly flexible during droughts in Sacramento Valley and in San Joaquin Valley respectively, as the opportunity cost of water becomes higher and crop insurance allows for income on land left unplanted (Sumner et al., 2021a; Rodríguez-Flores, et.al, 2021). Statewide, alfalfa and irrigated pasture are also more likely to see cut acreage or reduced (or "deficit") irrigation during droughts (Figure 3).

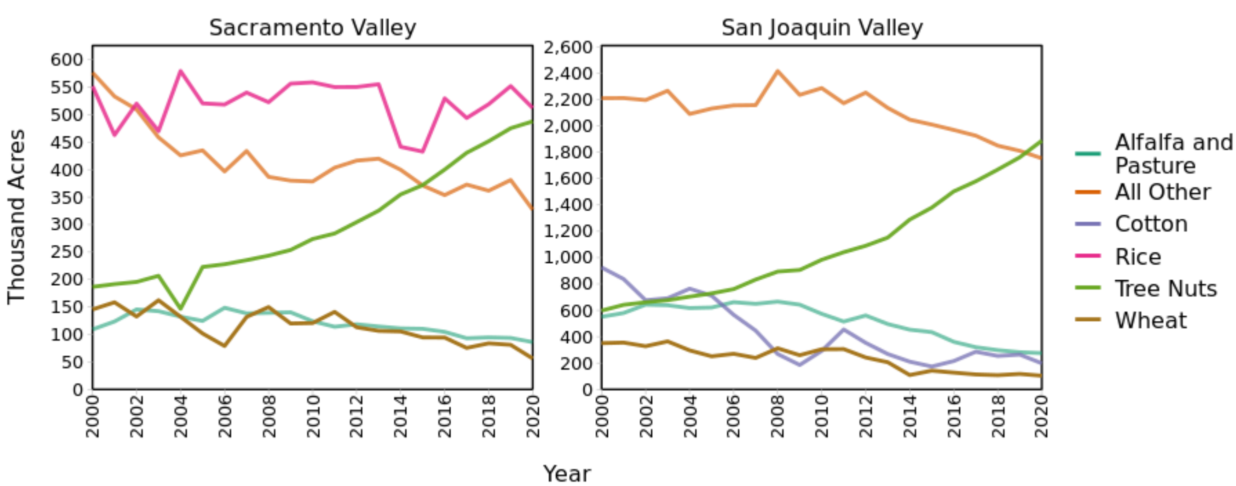

FIGURE 3. CROP ACREAGE TRENDS IN THE CENTRAL VALLEY. ADAPTED FROM RODRIGUEZ FLORES ET A. (2021) WITH DATA FROM: USDA-NASS, CALIFORNIA FIELD OFFICE (2022).

Droughts present challenges to California's agriculture in more than one way. The challenges include reduced irrigation water availability, less rain on pasture, increased production costs and lower crop yields. Foremost for most growers is water availability for irrigated crops, which constitute 77% of all farm revenue in California (USDA-ERS, 2022)[2]. As water supplies tighten, especially when additional groundwater is not available, adaptations can take the form of idle land, deficit irrigation, or rearranging of cropping patterns. Such adaptations vary depending on several factors, most importantly access to groundwater and surface water supply. The economics of farm production includes crop prices, costs of applied irrigation water and expected crop yields, which in turn can be affected by climatic factors as well as deficit irrigation.

In this report, we estimated changes in irrigated agricultural areas in 2021 with respect to the corresponding 2018 agricultural landscape in the Central Valley floor, the Russian River Basin and agricultural areas within Lassen, Modoc, Shasta and Siskiyou Counties. The crop area coverage in this report represents about two-thirds of the agricultural value in the state (including milk production). The other third of agricultural value is in other coastal, and southern inland agricultural regions. The Central Valley hosts the highest share of agricultural land compared to all other areas in the state, producing more than 300 agricultural commodities. The Russian River Basin irrigated commodities are dominated by wine grapes, orchards, other specialty crops, and rainfed forages. The northern intermountain valleys grow mostly forages and limited amounts of specialty crops, allowing some flexibility in irrigation during droughts.

To quantify the economic impacts of drought on irrigated agriculture, we estimate the net water cutbacks to each agricultural area with respect to a recent 15-year average (2002-16) to predict resulting cropping patterns. Then we assess economic impacts relative to prices and other economic indicators for the baseline year (2018). We also consider impacts on dairy and beef cattle industries in the study areas relative to this baseline.

Some caveats are worth noting. First, ongoing changes in irrigated areas (including expansion of some commodities), due to economics, regulations and other drivers can make it challenging to isolate drought impacts relative to a single year baseline. For example, tree nut acreage expansion has so far been less responsive to drought and more responsive to market forces. Second, variation in global commodity prices is mostly not a response to California drought. At the same time, lower yield for some California crop commodities may drive up prices and thus create more value even at reduced production output or during droughts. In some cases, nationwide prices on certain commodities, such dairy products, may play a more prominent role in cropping decisions of forage crops than water supply conditions. Third, as discussed below, there

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[2] The other 23% of all agricultural revenue is in the livestock sector, which includes some segments affected by drought in crop production.

are significant delays—and some ongoing gaps—in reporting on surface water and groundwater use by California agriculture, making it necessary to estimate those volumes—and the extent of cropland irrigation they make possible. All these factors—along with lags in statistical reporting on crop acreage and other series—make our current projected impacts preliminary. Future retrospective analyses are likely to provide greater certainty in estimated economic impacts.

Water Supply Overview

California's irrigated agriculture is supplied by a portfolio of water sources including surface water diversions from state (State Water Project, SWP), federal (Central Valley Project, CVP), and local agency projects, and groundwater. During dry years, the reduction in surface water availability is mitigated partially by using reserves stored in surface reservoirs (*i.e.*, carryover storage) and by increasing groundwater pumping. Water trading, where available, also helps reduce the economic toll of droughts by reducing shortages to specialty crops that generate higher value per unit of water used.

Reconciling announced cutbacks from federal and state water projects, water rights and other local supply cutbacks, groundwater replacement – and corroborated with remote sensing-based information on changes in actual evapotranspiration – we estimate surface water losses of about 5.5 maf, which after groundwater pumping augmentation, results in a net water shortage of 1.34 maf (8.4% of baseline) in the Central Valley, at least 27 taf (31% of baseline) within the Russian River Basin study areas, and 2 taf (8.2%) in the Scott Valley and Shasta Valley intermountain areas. Appendix A provides more details on the estimations, and Table 1 summarizes our preliminary water supply impacts for 2021. Information on groundwater replacement and dryland agriculture currently is less clear for the Russian, Scott, and Shasta basins, so these estimates will be refined for our final report. In what follows, we provide more detail to our preliminary water supply estimates for the 2021 drought year.

To assess the economic impacts of the drought, we first determined regional water availability by estimating the reductions in surface water deliveries and the increase in groundwater pumping (Appendix A). Reductions in surface supplies were obtained from multiple sources, including comparing 2021 water allocations for the SWP and CVP with 2000-2020 average water allocations, adding the reported water right curtailments from the State Water Resources Control Board (SWRCB), and estimating additional reductions in local water deliveries by comparing surface deliveries from reservoirs in 2021 with deliveries during the 2012-2016 drought. We calculated increased agricultural groundwater use by estimating the pumping response to surface shortages using the Department of Water Resources Water Balance Data (DWR, 2022), comparing local conditions with those in the 2012-2016 drought.

TABLE 1. 2021 DROUGHT WATER SUPPLY IMPACTS IN 2021 WITH RESPECT TO A RECENT 15-YEAR (2002-16) WATER SUPPLY BASELINE (IN TAF/YR).

Region	**Baseline Surface Use**	**2021 Surface Deliveries**	**Estimated Surface Water Cutback**	**Groundwater Replacement**	**Net Water Shortage**	**Net Water Shortage %**
Sacramento River	7,000	5,553	1,447	691	756	10.8%
San Joaquin River	5,900	4,852	1,048	964	85	1.4%
Tulare Lake Basin	8,652	5,644	3,008	2,509	499	5.8%
Central Valley Subtotal	**21,553**	**16,049**	**5,503**	**4,164**	**1,340**	**6.2%**
Northern Intermountain*	21	19	2	N/A	2	8.2%
Russian River*	87	60	27	N/A	27	31.0%
Total All Regions	**21,660**	**16,128**	**5,532**	**4,164**	**1,369**	**6.3%**

*Land use subset based on water rights, 2018 demands and potential cutbacks in 2021.
**Russian River Basin excludes non-irrigated areas and sub-basins in Dry Creek, Santa Rosa, and Bodega.

As detailed in the following sections, water shortages in the Sacramento Valley were higher than at any time in the 2012-2016 drought, while shortages in the San Joaquin River and Tulare Lake basins were like the early stages of the 2012-16 drought. Drought conditions were also exceptional for the Russian River Basin, and the northern intermountain agricultural areas including Scott, Shasta and Butte valleys in Siskiyou County, where notices of water unavailability and curtailments during the 2021 growing season were unprecedented. Groundwater augmentation reduced drought costs, but caused significant groundwater declines, especially in the Sacramento Valley but also other groundwater stressed basins. These ongoing water depletions—combined with less natural replenishment of groundwater basins during drought—also caused about 1,000 domestic wells to go dry statewide during 2021 (Household Water Supply Shortage Reporting System, 2021). The costs of groundwater pumping have also continued to increase due to a combination of increased demand for well development and lower depth to groundwater levels (*i.e.*, higher energy demand to bring water to the surface).

Central Valley

Total surface water shortages for Central Valley farms were about 5.5 million acre-feet (maf). Reductions in water deliveries from local projects were about 3.2 maf–including 850 taf of water right curtailments. For the State Water Project, water delivery reductions for farms were 452 thousand acre-feet (taf), compared to an average 2000-2020 supply of 530 taf. Central Valley Project shortages were estimated at 1.1 maf, or 52% of the average 2000-2020 delivery.

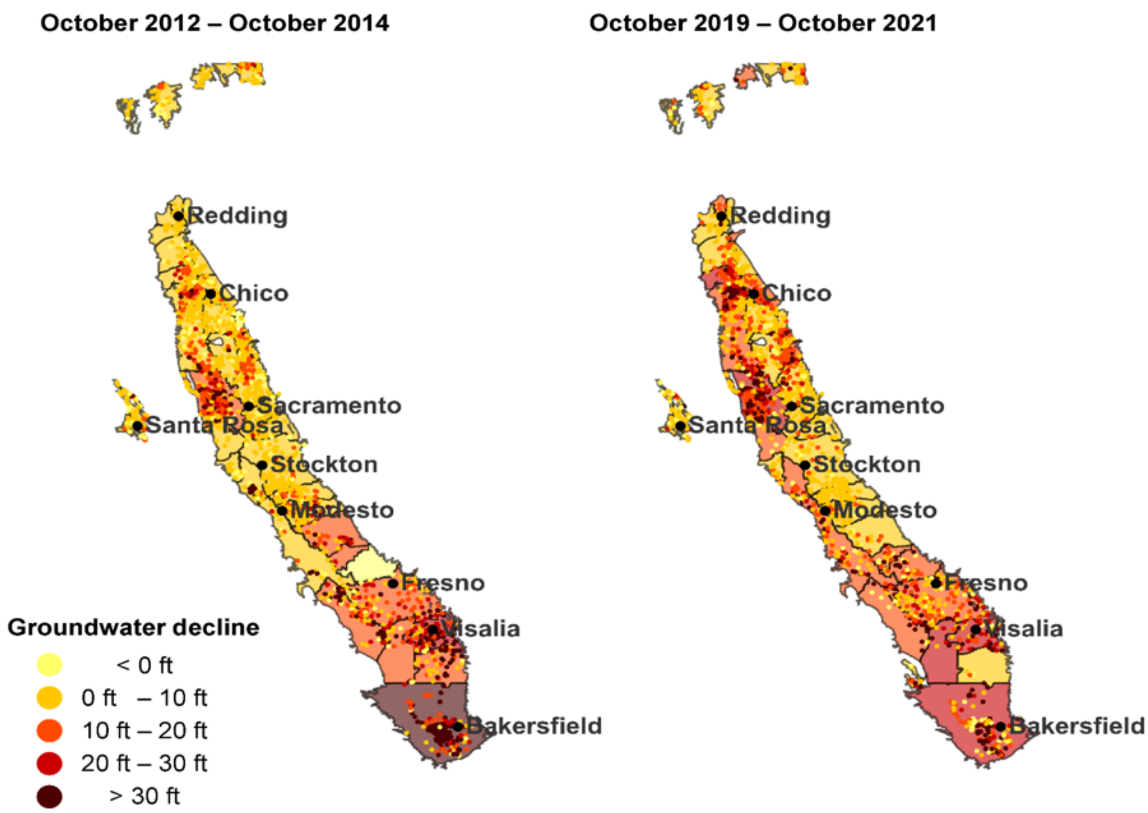

FIGURE 4. GROUNDWATER DECLINES BETWEEN OCTOBER 2012 AND OCTOBER 2014 (LEFT) AND OCTOBER 2019 AND OCTOBER 2021 (RIGHT). THE DOTS SHOW INDIVIDUAL WELLS, WHILE THE AVERAGE DECLINE PER BASIN IS SHOWN AS THE BASIN COLOR.

Surface deliveries in the Sacramento Valley in 2021 were less than in any year of the 2012-2016 drought–reflecting the precipitation deficits shown in the climate synopsis section. In the San Joaquin Valley, the surface water conditions were less severe than in the height of the 2012-16 drought, worsening generally from north to south. While the surface cutbacks in the San Joaquin River region were slightly less than in 2014, conditions in the Tulare Lake Basin were worse than in 2014, but not as severe as in 2015.

As in previous droughts, increased groundwater pumping reduced the impacts of surface shortages, especially where surface water from carryover storage or water trading was unavailable or postponed for later use in the 2022 growing season. The increase in groundwater pumping was almost 4.2 maf compared with the recent 15-year average [that we use as our baseline for water supplies] (2002-2016). Eighty-three percent of this extra pumping was in the San Joaquin Valley (about 1 maf in San Joaquin River basin, and 2.5 maf in the Tulare Lake basin), while the Sacramento Valley pumped an additional 700 taf. The San Joaquin Valley has more infrastructure to pump additional water in dry years because of historical adaptation to a more variable supply in the region. Typically, the Sacramento Valley has a more reliable surface water supply, making access to groundwater less important, but the exceptional conditions of 2021 showed a vulnerability for the region and its more limited water supply portfolio during droughts.

The comparison of groundwater level declines between 2012-2014 and 2019-2021 (Figure 4) provides additional insights about how conditions have changed between early in the last drought and this current drought. In the Sacramento Valley, where this drought began much stronger, groundwater levels have fallen more significantly—likely reflecting both increased groundwater pumping and less natural replenishment. In contrast, groundwater depths fell more significantly in some parts of the San Joaquin Valley in 2012-14 than in the past two years. This data suggests the early effects of SGMA regulation on pumping in some areas of the San Joaquin Valley.[3]

Net water shortages in the Central Valley, after additional groundwater pumping, were about 1.34 maf. The largest cutback in irrigation water deliveries was in the Sacramento Valley, almost 760 taf of net shortage—more than half of the total reduction in water availability in the Central Valley. The Tulare Lake Basin follows with roughly 500 taf of net water shortage, while San Joaquin basin net shortage was about 85 taf. Given differences in acreage and applied water in the different regions, the percentage of irrigation water use reductions compared to the 2002-2016 period was almost 11% in the Sacramento Valley, less than 1% in the San Joaquin basin, and about 6% in the Tulare Lake Basin (Figure 5).

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[3] For instance, groundwater sustainability agencies in the Tule sub-basin had groundwater allocations and pumping restrictions in place during the 2021 growing season. Some other basins were in the process of adopting allocations and establishing mechanisms to enforce them, along with pumping fees. Growers in some areas also have reported increasing groundwater storage in dry years as a hedge for continued drought. It is still early to assess the impact of SGMA on overall pumping in the region.

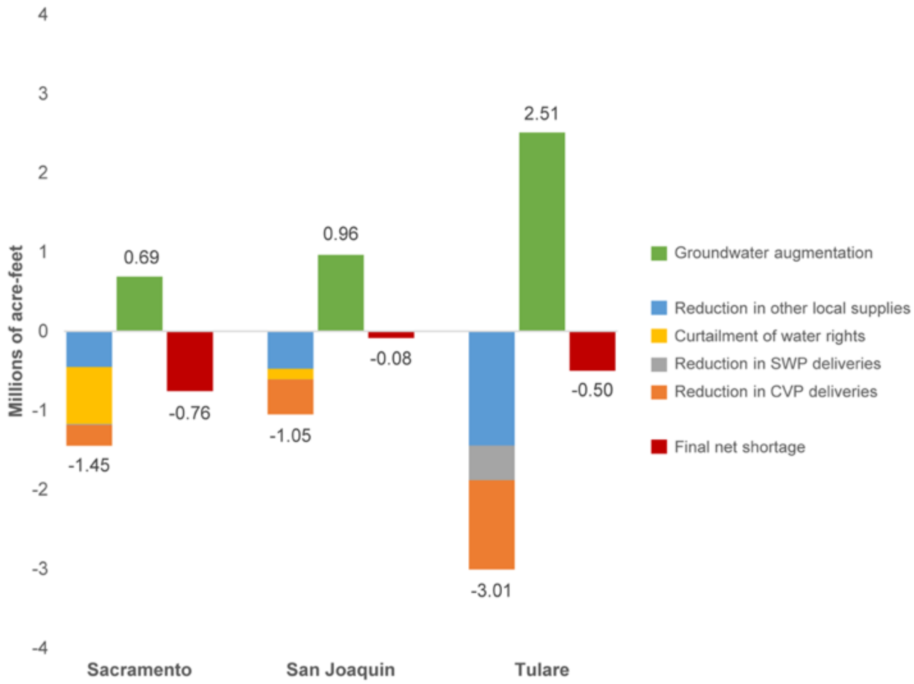

FIGURE 5. ESTIMATED CHANGES IN SURFACE WATER USE IN IRRIGATED AGRICULTURE AND GROUNDWATER REPLACEMENT IN THE CENTRAL VALLEY DURING THE 2021 WATER YEAR DURING COMPARED TO THE 2002-16 PERIOD

Russian River Basin and Northern Intermountain Valleys

During the current drought the Russian suffered from extreme dry conditions, triggering a declaration of emergency, even before other places in the state, early in the 2021 water year (Callahan, 2021). Changes in water use for irrigation of agricultural areas in Modoc, Siskiyou and Shasta counties during 2021 are more uncertain than the results obtained for the Central Valley, yet the team employed remote sensing information on actual evapotranspiration to approximate changes in irrigation, idle land and potential yield losses. While the agricultural land and water use in the Russian River basin is much smaller than the Central Valley, its agricultural value is primarily in wine grape and wine production, which can increase water shortage economic impacts. Commodities in the northern intermountain valleys are mostly forage crops.

Water supply reductions in the Russian River basin occurred during 2021. Regulation requires Lake Mendocino storage to exceed 20 taf by October 1st. Downstream from Lake Mendocino in the Russian River basin, the Potter Valley and the Redwood irrigation districts, as well as lands in the upper Russian River basin had reduced diversions for irrigation. Water delivery curtailments of at least 27 taf in the Russian River basin for irrigated agriculture were estimated based on published data by the State Water Resources Control Board (SWRCB, 2021). This is a reduction of roughly 31%

with respect to the SWRCB 2018 estimated diversion demand (Appendix A). Users in the Potter Valley received a 25% water allocation (Mendocino County Department of Agriculture, personal communication, February 2021).

Agricultural preliminary water use reductions from drought in the Scott River and Shasta River Basins are estimated at 1,710 acre-feet with respect to 2018 SWRCB estimated diversion demand. (We note that limited availability of data makes these estimates more uncertain.) Other regions including Butte Valley, Tule Lake, and Pit River areas also had some reductions in available water, which are still being calculated. Preliminary net water cutback estimates range from 10% to 25% reductions in water use in irrigated agriculture in these areas.

Remote Sensing-Based Changes in Crop Consumptive Water Use

To cross-check the regional water shortage estimates obtained above and idle land, the team used changes in large-scale estimates of actual evapotranspiration within a selection of agricultural areas (Figure 6). Estimated actual evapotranspiration (ETa) in June, July and August of 2021 was compared to the average estimated ETa of 2017 to 2020 from the MODIS SSEBop product.

Figure 6 shows the differences (anomaly) in actual evapotranspiration (ETa) in June, July, and August between 2021 and the 2017-2020 average. Differences are shown in inches of ETa. The mapped brown areas show places in which actual evapotranspiration is less than the 2017-2020 average conditions, suggesting changes in cropping patterns, deficit irrigation, increases of idled land or a combination of these factors. In contrast, mapped green-blue areas show places in which higher summer ETa occurred in 2021, suggesting increased irrigation, increased evaporative demands, or a combination of both. This spatial analysis indicates substantial decrease in evapotranspiration for many districts in the Sacramento River Basin compared to 2017-2020 conditions, and either no change or increased evapotranspiration for areas in the San Joaquin Valley over the same period, with some marked exceptions in the west side of the San Joaquin Valley, Kings, west of Tulare County and in Kern County.

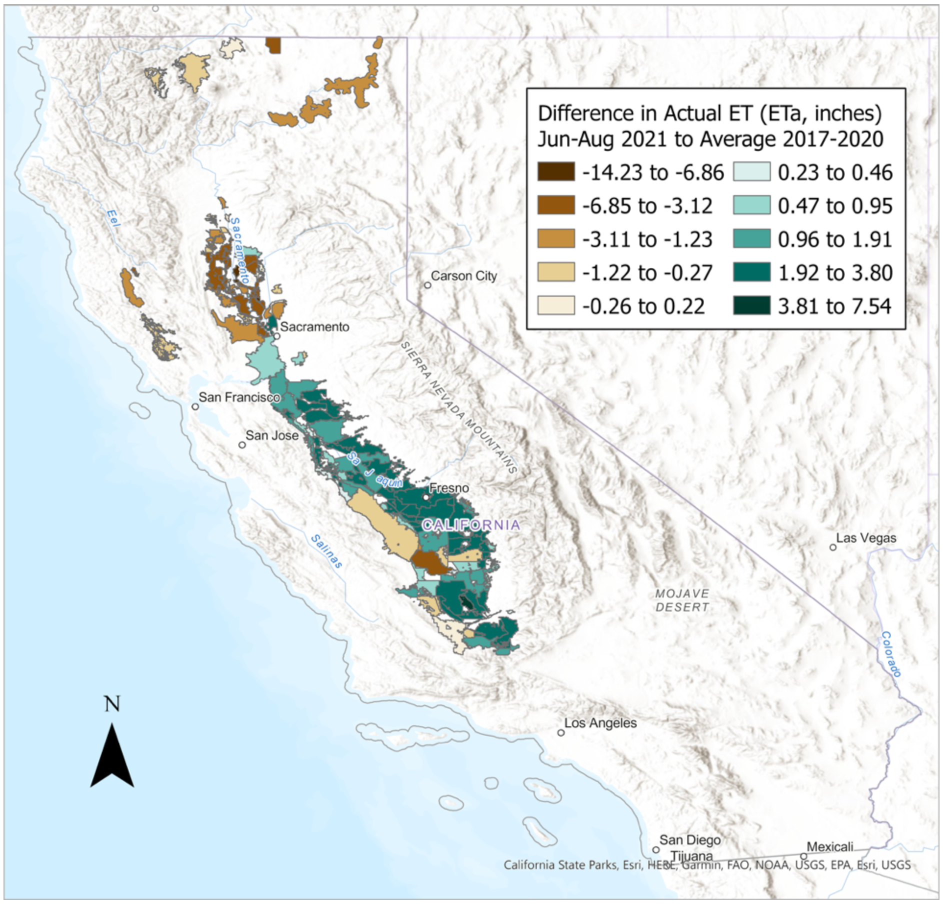

FIGURE 6. DIFFERENCE (ANOMALY) BETWEEN 2021 AND 2017-2020 AVERAGE EVAPOTRANSPIRATION DURING JUNE, JULY AND AUGUST. AREAS IN GREEN INCREASED CONSUMPTIVE USE WITH RESPECT TO THE 2017-20 AVERAGE, WHILE AREAS IN BROWN HAVE DECREASED CONSUMPTIVE USE DUE TO INCREASED IDLE LAND, DEFICIT IRRIGATION. SOURCE: MODIS SSEBOP PRODUCT FOR A SELECTION OF AGRICULTURAL AREAS.

When the percentage changes in consumptive use within the selection of districts (Figure 6) are extrapolated to greater areas in the Central Valley, net water shortages are estimated at 1.48 maf (compared to 1.34 maf estimated in the previous section).[4] Changes in consumptive use using remote sensing confirm the water supply shortage patterns described earlier in which most major irrigation water use reductions with respect to 2017-2020 conditions occurred in the northern parts of the state.

Changes in Cropping Patterns and Idle Land

Based on the net water cutbacks in the Central Valley and other areas, the team adapted hydro-economic methods in Medellín-Azuara et al. (2015) to predict potential cropping

[4] The difference of roughly 150 taf in shortage can be explained in part by the extrapolation of the regions included in the remote sensing analysis.

patterns. Use of statistical information from commodity groups from USDA-NASS and USDA-FSA (Appendix B), and personal communications with various interested parties were also considered in estimating total idle land due to drought, with respect to 2018 baseline land use and commodity values. Table 2 below summarizes the impacts of water shortages on irrigated areas by region.

TABLE 2. BASELINE 2018 IRRIGATED ACREAGE AND 2021 IDLE DROUGHT LAND SUMMARIZED BY REGION (IN THOUSANDS OF ACRES).

Region	**Baseline 2018 Irrigated area**	**2021 Irrigated area**	**Estimated additional drought idled land**
Sacramento River	1,586	1,339	246
San Joaquin River	2,103	2,093	10
Tulare Lake Basin	2,681	2,552	129
Central Valley Subtotal	***6,370***	***5,984***	***385***
Northern Intermountain	271	261	10
Russian River Basin	71	71	0
Total All Regions	**6,713**	**6,316**	**395**

The total estimated fallow land on irrigated agriculture for the regions in the study during the 2021 drought is estimated at 395,000 acres. Within the Central Valley, fallowing is estimated at 385,000 acres idled, about 10% lower than the estimates from the 2014 drought of 428,000 acres (Medellín-Azuara et al. 2015). Within the Sacramento Valley, drought-induced rice fallowing was estimated to be at least 100,000 acres, based on the USDA-FSA prevented rice acres report for 2021 and modeling results; the total could be higher if some fallowing also occurred on lands not enrolled in the crop insurance program. The rest of the fallow land is reduced field and grain crop acreages, with some opportunistic retirement of older trees. Drought-idled land in the San Joaquin Valley was concentrated in the west side. Such land relies on CVP contract water deliveries, which received zero allocations in 2021, but growers there also have been able to obtain some water from transfers and carryover storage. The USDA-FSA program reports 67,000 acres of cotton prevented (Appendix A). Other idle land due to the 2021 drought in the San Joaquin Valley includes field and grain crops and some removal of older trees. Estimates of idle land by major commodity group are shown in Table 3 below.

TABLE 3. 2021 DROUGHT-RELATED IDLE LAND BY MAJOR CROP GROUP AND REGION (IN THOUSANDS OF ACRES).

Region	**Alfalfa Pasture**	**Corn**	**Other Field and Grain**	**Trees Vine**	**Vegetables and Non-Tree Fruits**	**Total**
Sacramento River	49	20	136	32	0	246
San Joaquin River	14	-7	-2	6	0	10
Tulare Lake Basin	17	-3	94	16	5	129
Central Valley	***80***	***10***	***228***	***54***	***5***	***385***
Northern Intermountain	8	0	2	0	0	10
Russian River	0	0	0	0	0	0
Total All Regions	**88**	**10**	**230**	**54**	**5**	**395**

Although the estimated acres fallowed this year and in 2014 in the Central Valley are roughly comparable, we found a much higher share of fallowing in the Sacramento Valley this time (64%) than in 2014 (37%). In some cases, like in Kern County a decrease in idle land with respect to pre-drought conditions was seen for 2021 (Appendix D). There are numerous explanations for the higher idle land estimates in the Sacramento Valley relative to the San Joaquin Valley, including (a) much drier conditions during the 2021 water year in the Sacramento Valley compared to past droughts, (b) comparative lack of pumping capacity, (c) sales of water from Sacramento Valley to areas south of the Delta, and (d) more costly water, which can make production of some field and grain crops less profitable.

Economic Impacts

Irrigated Agriculture

Drought-related idle land is the major source of economic losses to agriculture during droughts. Gross revenue losses from drought idle land provide a starting point to estimate such economic losses. However, decreased yields due to deficit irrigation or climate factors may also affect gross revenues per acre and increase production costs, further reducing crop profitability. While this study cannot fully capture farm-scale nuances in production, the team surveyed drought-related yield changes for major commodity groups. Using 2018 land cropping patterns, yields and revenues as the baseline, crop revenue losses are estimated at $962 million for 2021.

TABLE 4 below summarizes gross revenue losses by region and commodity group. The Central Valley has the higher share of the losses ($755 million) followed by the Russian River Basin with $148 million. While fallow land in the Russian River Basin was not significant, yield declines in vines in Mendocino and Sonoma counties constitute the major source of economic losses (Appendix C). Some deficit irrigation kept vines alive, but reduced their yield, consistent with recent county crop reports. Factors beyond drought, such as recent wildfires, also affected the quality of the grape crops, and record high wine grape production in 2018 and 2019 that lowered commodity prices relative to recent peaks have also influenced cropping decisions for vine crops in the Russian River basin. Furthermore, Sonoma County preliminary estimates indicate losses of at least 80% in dryland silage corn, hay, and non-irrigated pasture (Sonoma County Department of Agriculture, personal communication, January 2021).

TABLE 4. DROUGHT GROSS REVENUE LOSSES SUMMARIZED BY IRRIGATED CROP GROUP AND REGION ($ MILLION).

Region	Alfalfa Pasture	Corn	Other Field and Grain	Trees Vine	Vegetables and Non-Tree Fruits	Total
Sacramento River	46	19	200	118	34	419
San Joaquin River	14	-8	9	29	-2	42
Tulare Lake Basin	26	-4	150	100	21	294
Central Valley	***$86***	***7***	***359***	***247***	***53***	***755***
Northern Intermountain	48	0	10	0	1	59
Russian River	0	0	0	148	0	148
Total All Regions	**134**	**7**	**369**	**247**	**202**	**962**

For the northern intermountain valleys, most drought-related impacts on irrigated agriculture were in feed, grain, and field crops. Relatively late cutbacks in water deliveries show up as idle crop output losses from reduced alfalfa cuttings or lower pasture yields—rather than as idled land—since these crops were already planted. These estimates may change as crop reports and other data becomes available.

As noted above, using the 2018 baseline for prices and crop yields (Appendix C) may bias some of the estimates given recent changes in agricultural commodity prices. Such potential bias is uneven across commodities, and this will be examined in more detail in the final report.

Dairies and Beef Cattle

The 2021 drought was particularly hard on rainfed pastures in northern California. It also raised irrigation water costs for irrigated pastures. Irrigation costs also rose for hay, corn silage, and small grain silage crops. These California-produced forage crops serve as crucial inputs for dairy and beef cattle industries. Such impacts arise from the lack of rainfed winter pasture and high cost of water to irrigate beef cattle pastures, alfalfa hay, silage corn, winter wheat and pasture.

Higher milk prices and expected milk prices raise milk cow numbers, milk per cow and hence milk production. Higher milk prices also raise demand for feed including forage crops. The California average milk prices increased by about 13% above the pre-pandemic average of 2017-2019, which is compared to 7% for the national average. Comparing the same periods, alfalfa hay prices were 7% higher and silage prices were 43% higher. The result was an increase in California milk production by 4% in 2021, which was the same as national milk production (Figure 7) how California milk production was higher throughout 2021, even after the drought was well under way. The number of cows was the same as 2020, as was the national milk cow herd. With higher prices and higher production, California dairy revenue was up by 17.6% and is projected to be up again in 2022. The higher hay and silage prices offset a portion of higher revenue, and the cost of grains and oilseed from outside California also rose in 2021, as did labor costs.

Organic milk production regulations require at least 120 days in pasture, but waivers were granted in 2021 because pasture conditions were so deficient in the North Coast region where most organic production is located. Organic production has been under pressure recently because most organic sales are for beverage milk products, and that part of overall dairy milk demand has been declining. In addition, organic production has expanded outside of California.

Beef cattle prices were higher in 2021 than in the pre-pandemic years, with fed cattle prices up 4% and feeder cattle prices up 3%. The USDA-NASS January Cattle Report shows that the California total cattle inventory was up by about 1% from January 2021 to January 2022, compared with a 2% decline nationally. The beef cow inventory, which is almost completely pasture-based, grew by 3% for California compared to a 2% decline nationally. Beef replacement heifers showed no change in California compared to a 3% decline nationally. Overall, it is hard to find evidence that drought-induced declines in pasturage resulted in lower beef cattle inventories, as might have been expected. In 2021, there were drought conditions throughout much of the western United States, and it may be that production conditions were worse outside of California.

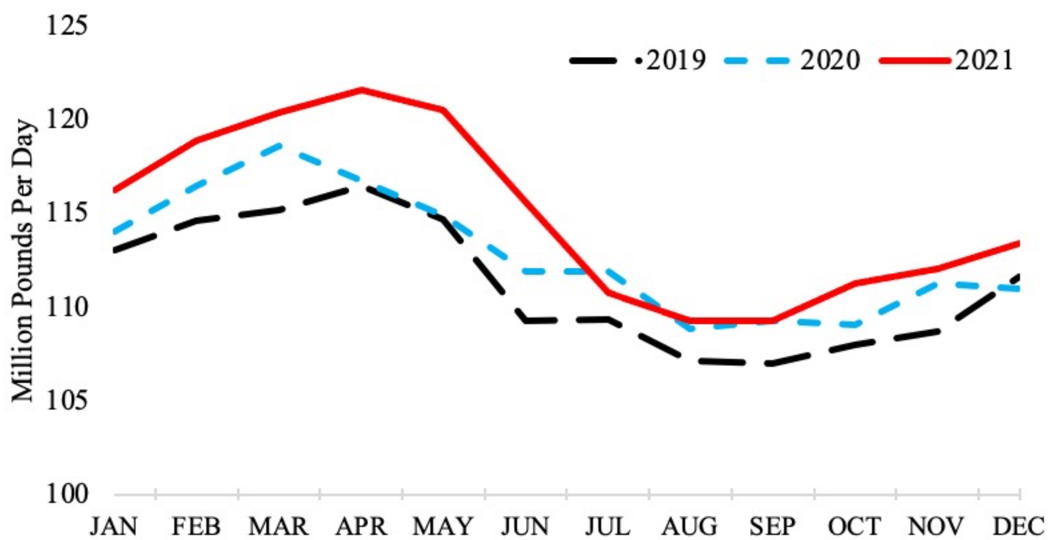

FIGURE 7. CALIFORNIA AVERAGE MILK PRODUCTION BY DAY. SOURCE: USDA NASS.

As with the crop sector, drought impacts vary by location and by individual circumstances. In sum, the negative economic impacts of drought on livestock production were mainly due to higher costs of production, which offset revenue gains of higher commodity prices (Sumner et al. 2021b).

Other Economic Costs

Irrigated areas with access to groundwater that faced surface water cutbacks turned to increased pumping to grow crops. Based on estimated changes in groundwater depths, the team calculated potential increases in pumping costs during 2021 of $184 million dollars for the Central Valley. A breakdown by region indicates $16.8 million for the Sacramento River Basin, $25.9 million for the San Joaquin River basin and $141.5 million for the Tulare Lake basin. Despite sizable increased pumping in the Sacramento River basin, shallower water tables result in lower pumping costs compared to the San Joaquin Valley at large.

Regionwide Economic Impacts

To estimate the economic region-wide agricultural impacts of the 2021 drought, gross revenue losses from crop farming were used to inform the IMPLAN input-output model (Appendix E). IMPLAN allows estimation of direct effects on employment, value added, and spillover (total) effects to agriculture-related sectors and the rest of the analyzed regions' economy. Table 5 below provides a summary of the regionwide economic impacts of the 2021 drought on agriculture. For 395,000 acres of drought-idled land and direct crop revenue losses of $962 million, and increased pumping costs of $184 million, full and part time job losses of 8,744 jobs and $611 million in value added could be expected. Once the spillover effects are considered, regionwide gross revenue losses of $1.7 billion, 14,364 full and part time jobs and nearly $1.1 billion in value added could be expected. Net economic impacts of the drought on the dairy and beef cattle sectors remain uncertain as increased gross revenues from stable or increased output, and strong milk prices seem to be offset by increased production costs.
These preliminary estimates provide a starting point to further explore drought vulnerabilities in California agriculture and identify areas that might become hotspots for unemployment and income loss. Such estimates will be refined as more information on idle land, economics of production and employment become available.

Limitations on this Preliminary Analysis

This preliminary analysis has inherent uncertainties. First, estimating surface water cutbacks presents some data challenges given the number of parties involved and the difficulties in setting an appropriate water use baseline, and the general lack of quantitative monitoring of actual diversions and use. Second, access to groundwater and pumping restrictions may vary widely, and most water supply hydrologic simulation models calculate pumping as a closing element in the water balance (*i.e.*, it is the least well parameterized term in the water balance and thus satisfies the actual unknown quantity plus uncertainty in other terms). This approach adds some layers of complexity in estimating groundwater availability for use in dry years. Third, yield impact assumptions may add uncertainties given the interplay between consumptive use, deficit irrigation and fallow land. Fourth, idle land occurs not only because of drought, but also as a function of external factors ranging from agronomic planning, land values and financing, and regulatory pressures. Environmental flow restrictions, water quality protection, crop rotation and commodity market conditions can compound other drought-related water scarcity conditions, making it difficult to dissect the drought effects of idle land. In some regions like the Russian River basin, idle land in irrigated agriculture can increase economic losses substantially. Thus, further exploration of drought-related idling in this region and a retrospective analysis of the 2012-2016 is ongoing.

TABLE 5. 2021 DROUGHT REGIONAL ECONOMIC IMPACTS FROM CROPS SUMMARIZED BY REGION. ESTIMATED FROM IMPLAN MULTIPLIER EFFECTS. THIS DOES NOT CONSIDER INCREASED PUMPING COSTS AND LOSSES IN THE LIVESTOCK SECTOR.

Region	**Fallow Land (1000 acres)**	**Direct Crop Revenue Losses ($M)**	**Estimated Pumping Costs ($M)**	**Total Economic Losses ($M)**	**Direct Employment Losses (Jobs)**	**Total Employment Losses (Jobs)**	**Direct Value-Added Losses ($M)**	**Total Value-Added Losses ($M)**
Sacramento River Basin	246	419	16.8	699	3,526	5,574	278	449
San Joaquin River Basin	11	42	25.9	87	471	824	25	52
Tulare Lake Basin	129	294	141.5	563	2,117	4,195	180	339
Central Valley Subtotal	***385***	***755***	***184***	***1,349***	***6,114***	***10,593***	***483***	***840***
Northern Intermountain	10	59	N/A	99	1,177	1,476	33	56
Russian River	0	148	N/A	257	1,454	2,295	94	163
Total All Regions	***396***	***962***	***184***	***1,705***	***8,745***	***14,364***	***610***	***1,059***

Preliminary Conclusions and Further Work

Every drought is different and brings new opportunities to innovate and become better prepared for future droughts. Undoubtedly, 2021 was the second year of an ongoing drought with a compounding effect on crop water demands and extremely low water supply in the northern part of the state. Should 2022 prove to be dry, the compounding effects of the previous two dry years will likely magnify impacts from surface water loss, such as additional idle land. This is occurring in the early stages of SGMA and its groundwater sustainability plan implementation. For some areas in the San Joaquin Valley, growers may have less flexibility to increase pumping to make up for surface water cuts than in past droughts. It remains unclear what the socioeconomic consequences will be if such shifts come to fruition. Some additional conclusions arise from this preliminary economic assessment of the 2021 drought on California agriculture:

1. The 2021 water year[5] was ranked as the third driest year statewide and second warmest year statewide since 1895. This followed a dry year with already low initial storage in reservoirs. Below average snowpack during 2021, low numbers of atmospheric rivers, and warmer temperatures continued to deplete storage in most reservoirs during 2021, with some like Mendocino Lake at historic lows.
2. Warmer temperatures and antecedent dry conditions increased crop evaporative demands, furthering the gap between water supply and crop irrigation. More research is needed to improve the understanding of the compounding effects of increased evaporative demands during droughts and the overall water balance.
3. Surface water supply shortages to agriculture were about 5.5 maf in 2021 compared to average 2002-2016 conditions in California's Central Valley. This volume is slightly lower than the estimated shortage of 6.5 maf during the 2014 drought. Increased pumping of roughly 4.2 maf served to partially offset surface water supply deficits, resulting in a net irrigation water supply reduction of 1.34 maf with respect to average 2002-2016 conditions, with an increased pumping cost of about $186 million.
4. In the 2021 water year, idling of rice fields in the Sacramento Valley, cotton in the San Joaquin Valley and other lower revenue row crops represented most losses in acreage. Much of the rice and cotton acreage left idle qualified for crop insurance payments. Removal of older trees and vine plantings increased somewhat during this drought with respect to previous years.

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[5] The 2020-2021 water year runs from October 1, 2020 to September 30, 2021.

5. Drought-related idle land is at least 385,000 acres in the Central Valley with 246,000 acres in the Sacramento Valley and 140,000 in the San Joaquin Valley.
6. Water cutbacks in the Russian River basin during this past year reduced local grape crop yields, without significant reduction in irrigated agricultural areas. Previous wildfires in the region reduced bearing acreage and sales of smoke-damaged grapes. Rainfed feed crops and pasture suffered sizable losses that affected some small organic dairy farms.
7. Curtailments in the northern intermountain valleys compared to baseline diversion demands were estimated at 2 taf based on publicly available data, and occurred late in the season, mostly affecting forage crop yields.
8. Animal production was affected by the 2021 drought from higher feed prices for forage crops grown in California, including pasture. Adaptations included imports of more hay. Higher hay and silage prices offset higher livestock revenue. Both milk production and dairy revenue increased substantially, reflecting strong market demand. Cattle numbers increased in 2021 compared to US totals. Estimates of revenues for animal operation will be updated in the final report.
9. The preliminary direct economic impact of the 2021 drought on crop agriculture in the study area is estimated at $962 million, with 8,745 full and part time job losses, and $610 million losses in value added. Spillover effects in the study's regional economies increase gross revenues losses to $1.7 billion, 14,634 full and part-time jobs lost and $1.1 billion losses in value added.

Improved information on actual water deliveries, crop reports from all agricultural areas and changes in agricultural employment will help improve this report's preliminary estimates in the next few later this year. Improved information will also bolster predicted outcomes from the suite of models employed in this analysis to support timelier planning and management efforts to weather future droughts in California agriculture.

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