

Analysis of effects of reduced supply of water on agricultural production and irrigation water use in Southern California

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**Josué Medellín-Azuara, Jessica A. Vergati, Daniel A. Sumner,
Richard E. Howitt and Jay R. Lund***

*Josué Medellín-Azuara is a Research Scientist, Department of Civil and Environmental Engineering and at the Center for Watershed Sciences, University of California, Davis.

Jessica A. Vergati is a Junior Research Specialist at the University of California Agricultural Issues Center.

Daniel A. Sumner is the Director of the UC Agricultural Issues Center and the Frank H. Buck Jr. Professor in the Department of Agricultural and Resource Economics, UC Davis.

Richard E. Howitt is a Professor in the Department of Agricultural and Resource Economics, UC Davis.

Jay R. Lund is the Director of the Center for Watershed Sciences, a Professor of Civil and Environmental Engineering, and currently the Ray B. Krone Chair of Environmental Engineering, UC Davis.

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Executive Summary

Agriculture in Southern California is large, vigorous and diverse. The crops in the region depend on ample irrigation water. To illustrate the vulnerability of agriculture and the broader economy to reductions in the supply of water, this study estimated the overall economic impacts of potential supply reductions of irrigation water in Southern California. For concreteness, we consider the effects of a 75 percent increase in the cost of irrigation water or a 25 percent reduction in the quantity of water available for irrigation.

To estimate the direct effects on crop farming in the major cropping areas of Southern California, we use the Statewide Agricultural Production Model (SWAP), an economic hydrological model. SWAP links irrigation water use to agricultural production through a set of supply and cost relationships based on a variety of primary data sources. We link our SWAP-based direct impacts to the IMPLAN model to estimate broader economic consequences.

We consider the impacts for inland counties and coastal counties separately and for Southern California agriculture as a whole. For Southern California as a whole, increasing the cost of irrigation water by 75 percent would reduce crop output by about \$251 million per year, or about three percent of the base value of crop output. A 25 percent cutback in irrigation water availability would reduce total Southern California crop output by about \$722 million or about eight percent of the base. The reductions in crop output would substantially affect the broader economy. The 75 percent cost increase would eliminate about 3,750 jobs and \$558 million of output from the Southern California economy. The 25 percent cutback in availability of irrigation water would have larger losses of about 9,960 jobs and \$1.59 billion in economic output.

For the coastal counties alone, increasing water costs reduces crop output by \$208 million, resulting in overall losses of \$459 million in economic output and 3,350 jobs. The coastal region accounts for about 90 percent of the economic losses for Southern California agriculture as a whole. A cut to coastal irrigation water availability reduces crop output by \$480 million per year, causing larger economic losses of 7,460 jobs and \$1.05 billion in total economic output. Coastal agriculture faces very high water costs (from \$100 to more than \$700 per acre-foot for coastal counties, versus \$20 to \$100 per acre-foot for inland counties), making water a large share of input costs for coastal farms. Thus, a 75 percent increase in water prices will make water costs prohibitively high for some coastal farms.

These impacts underestimate the importance of irrigation water to Southern California for three important reasons. First, because of a lack of data, our quantitative modeling could not include direct effects on the livestock industry, an important contributor to agriculture. Second, water district revenues are also impacted by changes in water supply and pricing. Third, farming contributes more than just income and employment to Southern California. Farms in the region provide locally produced food and an enrichment of the local environment that is difficult to measure quantitatively but is vital nonetheless. Agriculture plays a unique role in relatively urban regions, and cutting availability of irrigation water would threaten the viability of farming in Southern California.

1. Introduction and background

As in the rest of California, agriculture in Southern California relies on availability of water to irrigate the crops that contribute to the productivity of agriculture and the region's economy. The major crops in the region, including the coastal fruits and vegetables and the field crops further east, all rely on ample irrigation water. The greenhouse and nursery industry, which is difficult to model with the rest of agriculture, also needs substantial water. Without access to reliable and affordable irrigation water, agriculture in the region would literally dry up.

In this report, we explore changes in the opportunity cost of water due to water shortages, and revenue losses due to higher water prices. To consider the effects on agriculture and the economy of reducing the supply of water or raising its price, we combine the results of two model approaches. To study the impact on major crops in significant agricultural regions, we employ a variant of the well-known Statewide Agricultural Production Model (SWAP, <http://swap.ucdavis.edu>), a self-calibrated programming model of agriculture in California. We then calculate multiplier effects by employing the IMPLAN model for Southern California. This approach has been used several times for related questions (Lee, Sumner and Howitt, 1999).

California's water system is characterized by a marked asynchrony of water availability and demand both in space and time. Most availability is during the wet winters in the less populated north of the state while most water demands take place during the dry summers in the agriculturally-prominent Central Valley and the urban areas in the southern part of the state along the coastline. Figure 1-1 shows the share of runoff—the amount of local precipitation that flows into streams and recharges groundwater—across different regions and topological areas in California.

South of the Tehachapi Mountains, areas of heavy urbanization and heterogeneous agriculture face water challenges. In the South Coast Hydrologic Region, which includes San Diego, Los Angeles, Orange and Ventura counties, water use is predominantly urban. In 2005, total water use in the South Coast was 4.7 million acre-feet (MAF), from which 3.3 MAF were devoted to urban uses (California Department of Water Resources (DWR), 2009). In the Colorado River Hydrologic Region, which contains much of the inland counties of Riverside and Imperial along with the Coachella Valley and Palo Verde, water use is mainly agricultural. This inland region used a total of 4.5 MAF, of which 3.8 MAF went to irrigated agriculture. In both the South Coast and Colorado River regions (which exclude Santa Barbara County), an average total of 9.6 million acre-feet per year was used during the 1998 to 2005 period, according to DWR (2009).

During the past century, many infrastructural projects were undertaken to secure water for urban and agricultural uses in Southern California. In this region, water sources for all uses are predominantly surface water imported from other basins, including the Mono Basin through the Los Angeles Aqueduct, the Colorado River through the Colorado River Aqueduct, and from north of the state, through the State Water Project California Aqueduct (Figure 1-2). The Coachella and All-American canals in the southeast corner of the state provide water for agriculture in Coachella, Imperial and Palo Verde. Local surface diversions and groundwater, but mostly water imports from other basins, provide water to agriculture in the coastal areas of Southern California. These areas are particularly vulnerable to cuts in surface water allocations, in part because competing uses, such as from urban water demands, are often less flexible. Moreover, adjustments in ground water pumping are less available than in the Central Valley.

Groundwater use in Southern California is limited. In 2005, the net groundwater withdrawals were about 0.7 MAF for the South Coast and about 0.3 MAF for the Colorado River Region, or together, about 12 percent of total water use in both regions (DWR, 2009). In contrast to Southern California, the Central Valley relies heavily on groundwater sources for both agricultural and urban uses. Of the 10.7 MAF of total water use in the Tulare Lake Basin, 3.5 MAF were from groundwater sources. Lower availability of groundwater, which often offsets surface water cuts in times of stress, makes agriculture in Southern California more vulnerable to surface water cuts, especially since much of the surface water is for urban uses.

Agriculture in Southern California is heterogeneous. In the southeast region of the state, inland agricultural areas use 82 percent of agricultural applied water in Southern California, but have lower average crop values per acre than agriculture in the coastal areas of Ventura, Santa Barbara, Los Angeles, Orange and San Diego counties, which use the other 18 percent. Agricultural applied water use in Southern California was 4.0 million acre-feet per year in 2005, or a total of 4.7 MAF when including conveyance losses, such as evaporation and leaking from unlined canals (DWR, 2009).

In contrast, of the 5 million acre-feet used by urban areas in Southern California in 2005, 84 percent was used in the coastal areas. With the projected increases in urbanization, the California Water Plan Update 2009 estimates that by the year 2050, under current trends, there will be 20 percent less irrigated cropland area in the South Coast and 9 percent less in the Colorado River Region (DWR, 2009). Long-term water transfer agreements exist among agricultural and urban uses to support population growth. These include the transfer agreement between the Imperial Valley Irrigation District and San Diego. The Palo Verde Irrigation District has also engaged in water transfer programs, taking advantage of its relatively low consumptive use. However, transfers from east to west in Southern

California are limited by conveyance capacity in the Colorado River Aqueduct (Pulido-Velazquez et al., 2004).

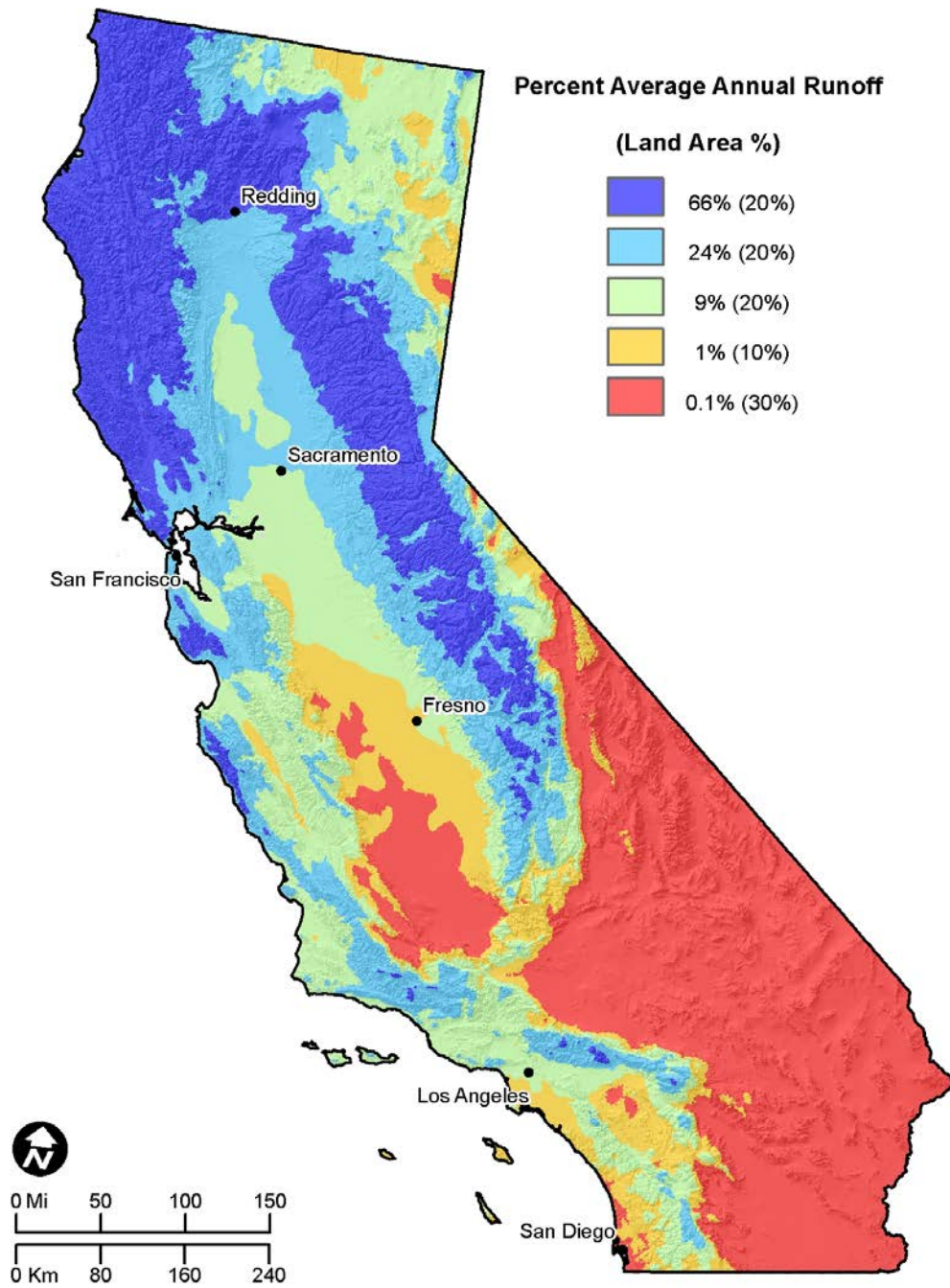


Figure 1-1. California precipitation map (Hanak et al., 2011)

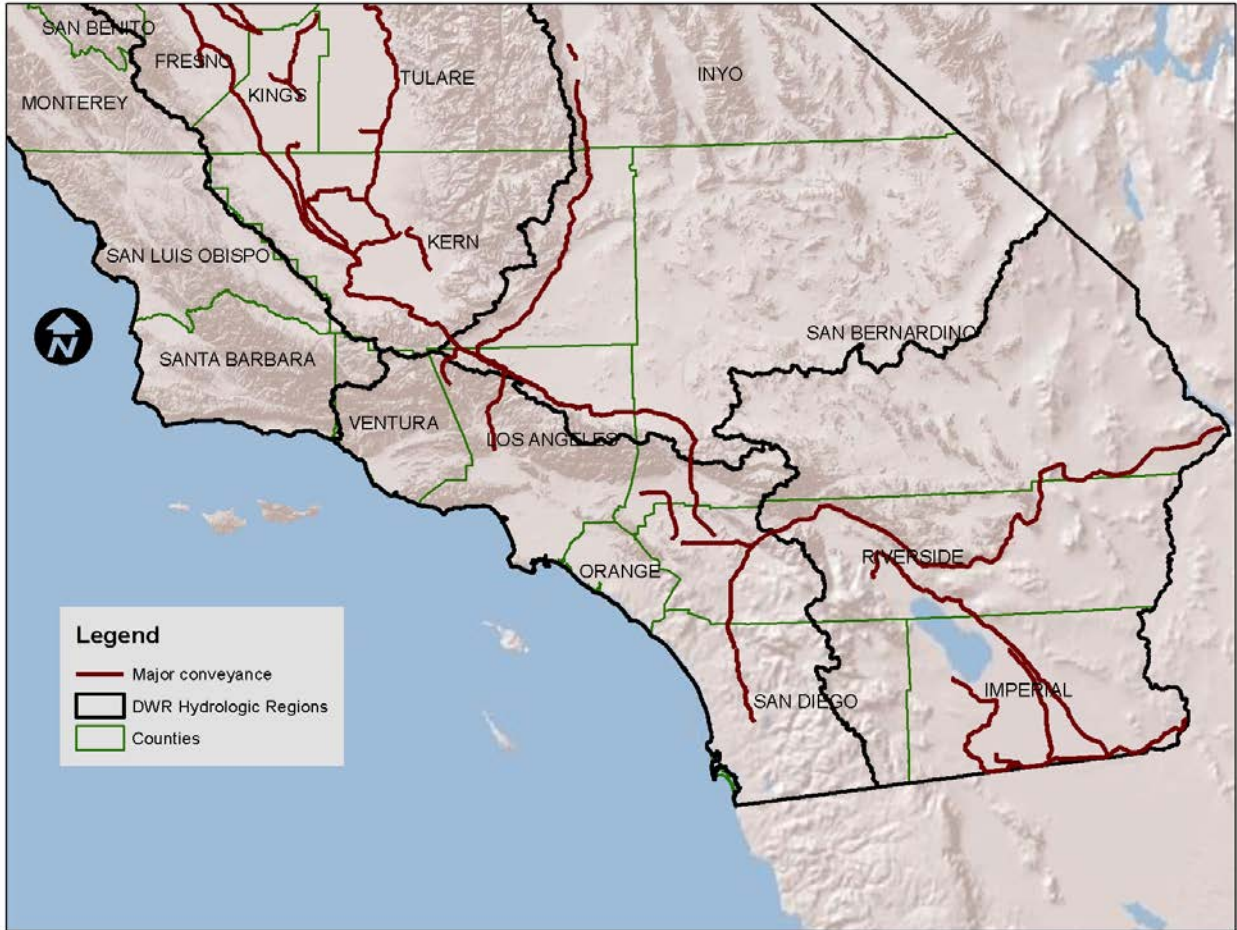


Figure 1-2. Southern California counties, hydrologic regions and conveyance infrastructure (Revised from Hanak, et al. 2011)

2. Water use and agricultural production by areas within the Southern California region

Agriculture in Southern California is diverse. Although there is agriculture in every county, the coastal counties of Ventura, Santa Barbara and San Diego, and the inland counties of Imperial and Riverside account for about 90 percent of the farm production value in the region (Table 2-1). The commodity mix differs greatly across counties. An amalgam of nursery plants, fruits, vegetables and livestock products comprise the list of top-valued Southern California commodities shown in Table 2-1. Southern California comprises 18 percent of total agricultural production value in the state.

Nursery and floriculture production together generate the highest value of all Southern California commodities, with \$1.9 billion in production value in 2010. About 58 percent of this output is in San Diego County, with significant production also in the other coastal counties and in Riverside County. Most agricultural production value in the highly urban Los Angeles and Orange counties is from nursery and flower production.

Fruit crops are key contributors to the value of agriculture along the coast and in Riverside County. Of the \$951 million in strawberry production, Ventura County produces \$542 million and Santa Barbara County produces \$355 million. Ventura and San Diego counties together generate nearly 80 percent of the value of avocados in Southern California. Lemon production is significant for the region as a whole, but is mostly in Ventura. Finally, Riverside and Santa Barbara each produce about \$100 million in grapes. Many other fruits are scattered throughout the region, but are not listed individually. For example, Ventura County produces \$221 million of other fruits, including raspberries and oranges.

Vegetable production in Southern California is widely dispersed. Lettuce is the top commodity in Imperial County, with about \$300 million in production value. The lettuce industry is smaller in Santa Barbara County, but also significant. Celery production is mainly in Ventura, while large amounts of broccoli are grown in Santa Barbara and Imperial. A myriad other individual vegetables and melons together make up one-quarter of Imperial County production value. These include onions, carrots and cantaloupes.

Production of field crops, livestock and livestock products is mainly in the inland counties. Imperial County grows about three-fourths of the hay and other field crops in Southern California, and produces much of the cattle, with a value of \$268 million in feedlot production. Milk production is also important in inland counties—with \$241 million in San Bernardino County and \$146 million in Riverside County. The \$193 million egg industry is located in Riverside, San Bernardino and San Diego counties. About 88 percent of agricultural production value in San Bernardino County is from livestock and greenhouse and nursery products that do not use significant amounts of district irrigation water.

Table 2-1. Top Southern California commodities by county agricultural production value, 2010^a

| | Imperial | Los Angeles | Orange | Riverside | San Bernardino | San Diego | Santa Barbara | Ventura |
|------------------------------|--------------------|--------------|--------------|----------------|----------------|----------------|----------------|----------------|
| | (\$ millions) | | | | | | | |
| Nursery and flowers | 4.1 | 107.9 | 90.0 | 169.3 | 28.7 | 1,107.6 | 178.1 | 227.4 |
| Strawberries | - | 0.8 | 29.6 | 10.2 | 1.3 | 11.5 | 355.2 | 542.1 |
| Lettuce | 301.3 | - | - | 36.6 | - | 2.5 | 101.3 | 14.0 |
| Milk | - | - | - | 145.6 | 240.8 | 7.9 | - | - |
| Avocados | - | 0.2 | - | 23.6 | 1.4 | 147.1 | 52.1 | 148.3 |
| Cattle | 267.5 ^b | - | - | 15.2 | 40.6 | 16.2 | 20.8 | - |
| Lemons | 19.7 | - | - | 69.0 | 0.8 | 39.0 | 12.7 | 174.8 |
| Celery | - | - | - | 5.6 | - | - | 40.8 | 182.3 |
| Broccoli | 75.3 | - | 0.04 | 11.4 | - | - | 122.5 | 4.1 |
| Tomatoes (all) | - | - | 0.2 | 1.5 | 0.1 | 86.8 | - | 120.1 |
| Grapes ^c | - | - | - | 99.5 | 0.4 | 0.8 | 97.4 | - |
| Chicken eggs | - | - | - | 71.3 | 45.7 | 75.9 | - | - |
| Hay | 228.8 | - | - | 54.8 | 11.8 | 1.0 | 2.9 | - |
| Other field and seed crops | 194.3 | 14.7 | 0.9 | 39.6 | 5.4 | 5.0 | 13.3 | 7.4 |
| Other fruits and nuts | 31.6 | 17.4 | 13.2 | 113.4 | 17.7 | 59.9 | 40.8 | 220.5 |
| Other vegetables and melons | 418.4 | 31.1 | 16.1 | 213.6 | 23.2 | 79.6 | 171.7 | 208.1 |
| Other livestock and products | 57.5 | 7.7 | 0.3 | 13.4 | 9.3 | 7.8 | 10.5 | 7.7 |
| All commodities | 1,598.5 | 179.8 | 150.4 | 1,093.7 | 427.6 | 1,648.6 | 1,220.0 | 1,856.7 |

Source: USDA, NASS, California Field Office (2011). California County Agricultural Commissioners' Data, 2010.

^a Commodities are listed in approximate ranking order by total Southern California county production value. A dash indicates no reported production by the County Agricultural Commissioners.

^b Feedlot cattle only, as reported by the Imperial County Agricultural Commissioner.

^c Grapes include table and wine grapes.

Due to the differences in crops grown across areas, revenue per acre differs significantly throughout Southern California. Figure 2-1 illustrates average per-acre revenues for California irrigated agricultural areas, including some in Southern California. Riverside and Imperial counties in the southeast have lower revenue per acre than the coastal region because they grow field crops and some vegetables, with fewer permanent crops. Coastal areas of Southern California concentrate more on permanent crops and strawberries than do inland areas. A higher value of agriculture per acre-foot of water implies larger costs of losing water in these more intensive cropping areas.

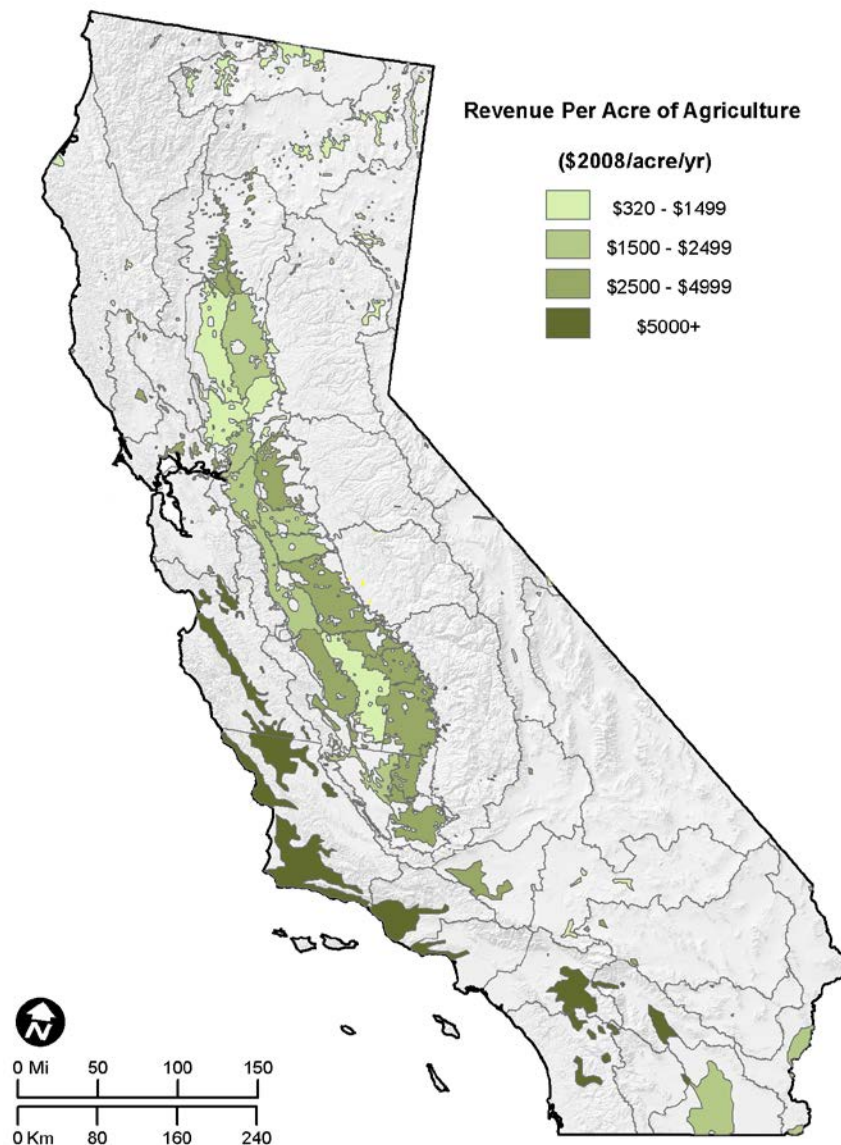


Figure 2-1. Agricultural revenues per acre for distinct irrigated areas in California (Hanak, et al. 2011).

Using water balances from the California Department of Water Resources, we estimate that annual applied water for all Southern California agriculture (including nursery and livestock) is about 4 million acre-feet, distributed among the counties as shown in Table 2-2. Most water use occurs in Imperial County, which has senior water rights on the Colorado River. Imperial agriculture used about 2.4 million acre-feet of water for irrigating crop and pasture land in 2005. Recall that 82 percent of Southern California applied water is in the three inland counties. Although Ventura County has the highest agricultural production value among Southern California counties, its annual amount of applied water (including groundwater) is about 10 percent that of Imperial. Applied water use is lowest in Orange and Los Angeles counties, which have little agriculture beyond nursery and floriculture production. When we account for water conveyance losses, such as evaporation or leaking of water from unlined canals, the total applied water use in Southern California becomes 4.7 MAF. According to the California Water Plan Update 2009 water balances, conveyance losses were mostly for Imperial County (see Table 2-2 footnote).

We find that crop revenue (excluding nursery crops) per acre-foot of applied water is about \$607 for the inland counties of Imperial, Riverside and San Bernardino. In contrast, revenue per acre-foot is roughly 7.5 times larger, or \$4,538 per acre-foot, in Los Angeles, Orange, San Diego, Santa Barbara and Ventura counties.

Table 2-2. Approximate applied water use in Southern California agriculture by county, 2005

| County | Applied Water (thousand acre-feet per year) |
|-----------------------|---|
| Imperial ^a | 2,355 |
| Los Angeles | 70 |
| Orange | 14 |
| Riverside | 804 |
| San Bernardino | 154 |
| San Diego | 196 |
| Santa Barbara | 195 |
| Ventura | 228 |
| Total | 4,016 |

Source: Authors' calculation using water balances from the California Water Plan Update 2009.

^a In addition to total applied water, Imperial County agriculture had significant water conveyance losses of 665.4 thousand acre-feet/year in 2005.

3. Agricultural economic impacts of water shortages and higher water costs

Previous studies reveal that reduced water supplies increase the marginal willingness to pay for irrigation water. The maps in Figure 3-1, from Hanak, et al. (2011), show differences across California in willingness to pay for water for irrigated areas, including some in Southern California. Larger water cutbacks (in the order of 25%) make the marginal value of water very high (greater than \$1,800/acre-ft) in some coastal regions of Southern California.

However, the Hanak, et al. study results and the maps in Figure 3-1 do not reflect directly the parameters of the study reported below. The method and magnitude of water reduction simulations differ, as do the geographical areas covered. Nonetheless, the high willingness to pay for irrigation water found in previous work indicates that the opportunity cost of water cutbacks in some parts of agriculture is comparable to that of urban uses (Bartolomeo, 2011).

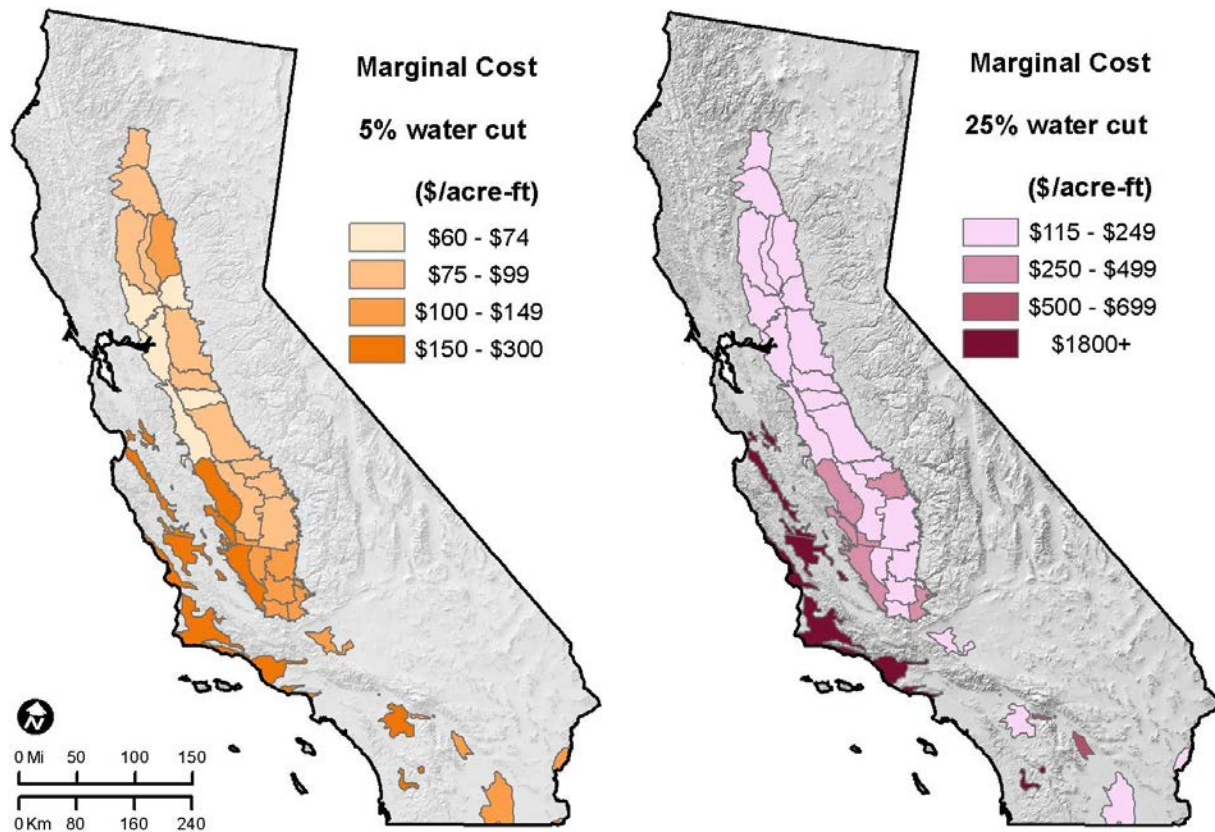


Figure 3-1. Marginal cost of a 5 and 25 percent water shortage in agriculture (Hanak, et al. 2011)

3.1 Modeling approach to assess initial agricultural impacts

We model the economic impacts of two scenarios in which irrigation water becomes less accessible for agriculture in Southern California. For both cases, we employ the SWAP model to data that derives primarily from the California Department of Water Resources.

The first scenario increases the base cost of water for irrigated agriculture by 75 percent for each SWAP agricultural region in Southern California. The second scenario reduces water availability from all sources including groundwater, surface water diversions and contract water in each SWAP agricultural area by 25 percent, holding water costs constant.

The SWAP model is a self-calibrated optimization model for major crop production in California. The SWAP model employs the 20 standard crop group definitions reported by DWR. These crop groups are: almonds and pistachios, alfalfa, corn, cotton, cucurbits, dry beans, fresh tomatoes, processing tomatoes, grains, onions and garlic, orchards, vegetables, pasture, potatoes, rice, safflower, sugar beets, subtropical fruits, and vines. Irrigated crop area and applied water for selected regions in the state follow estimates from the California Water Plan, corroborated with County Agricultural Commissioners' Reports.

Water costs differ within and between regions and crops. Allocation of irrigation water across crops and regions is restricted in some cases. In SWAP, crop yield and basic cost information is from UC Davis cost and return studies (<http://coststudies.ucdavis.edu>) and other sources and applied to a set of proxy crops in each SWAP crop group. Water cost data is primarily from DWR and local sources. Based on information from the cost and returns studies and from local irrigation districts, water costs average \$20 per acre-foot for crops in the inland counties. Coastal water costs are much higher. For the coastal counties, our application of SWAP uses water costs as follows: \$214.32/acre-foot for coastal vegetables and berries, \$660/acre-foot for coastal subtropical fruits (including avocados and citrus), and for all other coastal crops (including vine crops, field crops and other crops), water costs are \$129.44/acre-foot. In some cases, agriculture uses municipal water sources rather than agricultural irrigation water, making the cost of water even higher. However, this alternative cannot be formally modeled in SWAP.

SWAP agricultural regions correspond to irrigated crop areas following information from the DWR Water Plan Update 2009. Some of these areas cross county lines. The most disaggregated spatial unit is called the Detailed Area Unit; the model also uses Planning Area and Hydrological Regions defined by the DWR. The two hydrological regions analyzed in SWAP are the South Coast and the Colorado River regions.

Under both water scenarios, farmers respond by changing crop mixes and land use, effectively shifting the allocation of water use among crops in the region. Water allocation

across farms and water districts within and among Southern California agricultural regions has limited flexibility. The SWAP model approximates this limited flexibility by allowing full flexibility of water across farms within each agricultural region, and no water flexibility across regions.

We link farm impacts to the rest of the Southern California economy by entering the percentage losses in agricultural revenue implied by the SWAP model into the IMPLAN 2010 database and model. IMPLAN is used to estimate direct and multiplier effects of the policy scenarios modeled (Vergati and Sumner, 2012). Because the aggregations of crops in the two models differ, we approximated the match between crop groups in SWAP with corresponding crop groups in IMPLAN.

We used SWAP to estimate percentage revenue losses as a result of water cuts and water cost increases for each individual crop group and region. Once we reconciled the different crop groups between SWAP and IMPLAN, losses for individual SWAP groups were aggregated into a total percentage loss for the corresponding IMPLAN sector output (Table 3-1, columns 3 and 4). These were used as the direct revenue losses (sector output losses), which then translate through IMPLAN industry multipliers into broader economy-wide effects on output, employment and value added. The direct revenue effects for inland agricultural areas as a group calculated by SWAP were applied to the IMPLAN model for inland Southern California counties. Revenue changes from SWAP for the coastal areas were applied to coastal counties in IMPLAN. Then, the sum of direct output changes for both the inland and coastal regions were applied to IMPLAN for the full eight-county region to estimate broad effects on the regional economy. Only percentage changes were used from the SWAP model, not specific dollar losses.

SWAP does not include production relationships for livestock, poultry and dairy farms, nor for greenhouse and nursery operations. Livestock and livestock products, which represent about 6 percent of Southern California agricultural production value, were thus excluded from the SWAP cost and water availability modeling exercises. No direct effects of cuts to irrigation water apply to livestock farms. However, the feed and hay inputs are modeled. Livestock farms are mostly affected indirectly by these inputs. Greenhouse and nursery represents about 23 percent of regional agricultural production value. Because the vegetable and melon industry is similar in water use intensity to greenhouse and nursery, we apply the same SWAP percent revenue change due to water cuts on the vegetable and melon industry to the nursery industry.

Santa Barbara County is not included within the SWAP model for Southern California. It is part of the Central Coast Hydrologic Region. Water supplies for Santa Barbara and the southern Central Coast are mainly local groundwater, which totaled nearly 300 thousand acre-feet (TAF) in 2005. Imports from the Coastal Aqueduct branch of the state water

project, with a capacity of 71 TAF per year for San Luis Obispo and Santa Barbara, are also a significant water source for the area. Because Santa Barbara County is in a separate hydrologic region not covered in the Southern California SWAP model, we assume that percentage changes in Santa Barbara agricultural revenue due to water cuts are akin to those in the other coastal Southern California counties. We thus apply the overall revenue changes derived from SWAP for the south coast to the IMPLAN model for Santa Barbara County. Consequently, subsequent tables in this report include estimated impacts on Santa Barbara County along with the other southern counties.

3.2 Direct agricultural impacts of increasing water costs for all of Southern California combined

Increasing water costs by 75 percent caused revenue losses for all crop groups and sub-regions in SWAP. Raising the cost of water from its base cost per acre-foot causes total irrigation water use to decline and land to shift among crops towards those that use less water per unit of value. Effects are in the same direction in both inland and coastal counties, but the magnitudes are different.

Based on the SWAP results, for inland counties, where water prices are relatively low initially, a 75 percent water cost increase causes farmers to reduce their water use by an average of 10 percent. In coastal counties, the same cost increase causes an irrigation water use reduction of about 14 percent. Crop groups with the largest losses in revenue and acreage under increased water costs include the field crops that tend to be grown in Imperial County. The percentage reductions by crop group derived from the SWAP model were matched with crop group sectors in the IMPLAN model. We first report effects for the inland and coastal counties combined and then present the results separately. Because the two parts of Southern California have quite different mixes of growing conditions, water costs and crops, the impacts of changing water costs differ substantially between the two regions.

Table 3-1 shows the effects of the 75 percent increase in water costs on crop revenue (calculated from the SWAP model) for the aggregate crop categories that are used in the IMPLAN model for all of Southern California. Fruit farming, with a large share of production in the coastal counties, faces a loss of about \$176 million, or 7 percent of output. Field crops, including cotton, oilseeds, grains and other crops, which are grown mainly in the inland region, lose about \$40 million. For high-value vegetables and melons, the \$15 million loss is small in percentage terms.

Because the SWAP model does not include greenhouse and nursery, we assume that the revenue impact of water cuts on this industry can be approximated using the impacts on similarly water-intensive vegetable and melon farming, which also has higher revenue per unit of land and water. Irrigation water from agricultural sources is less important for nursery crops than for other crops, as greenhouse and nursery producers often draw from municipal water supplies. These crops also have a very high value of water and are less likely to cut back substantially from increases in water prices compared to, for example, irrigated field crops. From a base output of \$2.1 billion, greenhouse and nursery would lose about \$20 million when water costs increase, which is small in percentage terms.

Total direct revenue losses within agriculture are about \$250.5 million per year when water costs rise by 75 percent. This represents about three percent of total base revenue (\$9.07 billion in the second column) for the affected crop groups. The base crop output data in Table 3-1 is from the IMPLAN database and thus differs from the descriptive revenue data presented in Table 2-1.

Table 3-1. Estimated direct effects (as total revenue losses) from water cost increase and water availability reduction for Southern California farming (in 2008 dollars)

| IMPLAN Sector | Sector Output Losses | | |
|--|------------------------|---------------------------|-------------------------------------|
| | Base Sector Output | Water Cost Increase (75%) | Water Availability Reduction (-25%) |
| | <i>Million \$/year</i> | | |
| Cotton farming | 20.2 | -0.9 (-4%) | -4.3 (-21%) |
| Fruit farming | 2,506.3 | -175.9 (-7%) | -289.9 (-12%) |
| Vegetable and melon farming | 1,839.5 | -14.7 (-1%) | -84.7 (-5%) |
| Tree nut farming | 16.5 | 0.0 (0%) | -0.1 (-0.6%) |
| Greenhouse, nursery and floriculture production ^a | 2,122.5 | -20.1 (-1%) | -110.2 (-5%) |
| Oilseed, grain and other crop farming | 1,054.2 | -38.9 (-4%) | -232.9 (-22%) |
| Livestock and livestock products ^a | 1,511.4 | 0.0 (0%) | 0.0 (0%) |
| Total | 9,070.6 | -250.5 (-3%) | -722.0 (-8%) |

Sources: IMPLAN 2010 and SWAP modeling results applied to IMPLAN 2010.

^a Not modeled in SWAP.

3.3 Direct agricultural impacts of reducing water availability for all of Southern California combined

We next consider a 25 percent reduction in water availability to agriculture for every sub-region. Note this reduction is applied regionally, not by field or crop. Direct crop revenue losses for all of Southern California total about \$722 million per year if irrigation water availability were cut by 25 percent (third column of Table 3-1). This is approximately eight percent of the base crop group revenues.

For all IMPLAN categories of crop farming in Southern California, revenue losses are much higher under this scenario than when water costs increase. When water availability is cut, high revenue-per-acre crop groups such as fruits and vegetables face cutbacks, even if their revenue per acre would support maintaining irrigation water. This applies even as water is shifted from field crops, which have lower revenue per acre, because in some parts of Southern California there are few acres of low revenue-per-acre crops to draw from. A reduction in water availability will likely also have a more significant impact on the greenhouse and nursery industries, which are a large segment of agriculture in Southern California. If water quantities are reduced, producers of these high revenue-per-acre crops often cannot get physical access to more irrigation water, even if they would be willing to pay a higher price. This means large direct revenue losses for the most valuable parts of irrigated crop farming in Southern California.

As the final column of Table 3-1 shows, water availability reductions for low-value oilseeds and grains cause revenue losses of about \$233 million, or 22 percent. Similarly, cotton revenues fall by 21 percent. These crops tend to be grown in the inland counties in areas with few high value-per-acre alternatives. The revenue loss for fruit farming is \$290 million, or about 12 percent of base output, and revenue loss for vegetable and melon farming is an additional \$85 million.

3.4 Direct agricultural impacts of increased water costs and reduced water availability calculated for coastal and inland Southern California separately

Tables 3-2 and 3-3 show impacts for the coastal and inland counties of Southern California separately. Coastal counties include Santa Barbara, Los Angeles, Orange, Ventura and San Diego. Inland counties include Riverside, San Bernardino and Imperial counties. We consider the effects of water cuts on these areas separately for three main reasons. First, agriculture in the coast is much different from the inland counties. Inland agriculture focuses on field crops, livestock and vegetable (lettuce) farming, while coastal farming focuses on permanent crops, strawberries, vegetables and nursery production. Second,

inland counties, led by Imperial, use about 82 percent of applied agricultural water in Southern California and have much lower crop value per acre-foot. Last, coastal counties tend to have considerably higher water costs than the inland counties and concentrate on crops that have high returns per unit of water.

For coastal counties, an increase of 75 percent in water cost is estimated to have a large direct impact of \$208 million (4%) in lost crop revenues (Table 3-2). About 81 percent of this impact occurs in fruit farming, which loses \$168 million in production value. Coastal fruit farming already has relatively high water costs compared to other crops and regions.

When 25 percent less water is available to agriculture on the coast, the effects on agriculture are even greater than when water costs rise by 75 percent. Total revenue losses for coastal Southern California are about \$480 million when water supply is reduced by 25 percent (column 4 of Table 3-2). This represents a 9 percent fall from base output. Fruit revenue falls by 10 percent when water costs rise and 15 percent when water supply is cut. Coastal oilseeds, grains and other crops lose 53 percent of base revenue when water supply is cut as farmers shift water use to higher revenue-per-acre-foot crops.

Reduced water supply has a smaller impact on inland agriculture, where water costs are significantly lower than in the coastal counties (Table 3-3). In the inland areas where most of the irrigation water is applied and most of the crops are grown, water costs are low enough that water does not comprise a large share of total costs. We calculate that a 75 percent increase in water costs causes a \$43 million (1%) annual loss in inland agricultural revenue. Most of the main crops already have relatively low revenue per acre, so relatively little of that cropland would be idled in response to higher water costs in the inland region. A 25 percent water cut causes a \$242 million (6%) loss. Roughly three-quarters of the losses due to reduced water availability for inland farming are from cotton and other field crops (“Oilseed, grain and other crop farming”). Collectively, these crops lose about \$188 million, or 19 percent of base output value. When less water is available, farmers shift water out of field crops, but only some of that land is able to shift to crops with higher revenue per acre-foot.

Table 3-2. Estimated direct effects (as total revenue losses) from water cost increase and water availability reduction for farming in coastal Southern California^a (in 2008 dollars)

| IMPLAN Crop Group | Sector Output Losses | | |
|--|-----------------------------|----------------------------------|--|
| | Base Sector Output | Water Cost Increase (75%) | Water Availability Reduction (-25%) |
| | <i>Million \$/Year</i> | | |
| Cotton farming | 0.0 | 0.0 (0%) | 0.0 (0%) |
| Fruit farming | 1,739.3 | -167.5 (-10%) | -268.1 (-15%) |
| Vegetable and melon farming | 1,125.6 | -11.7 (-1%) | -62.5 (-6%) |
| Tree nut farming | 11.1 | 0.0 (0%) | 0.0 (0%) |
| Greenhouse, nursery and floriculture production ^b | 1,811.9 | -18.8 (-1%) | -100.6 (-6%) |
| Oilseed, grain and other crop farming | 92.4 | -9.5 (-10%) | -48.9 (-53%) |
| Livestock and livestock products ^b | 281.3 | 0.0 (0%) | 0.0 (0%) |
| Total | 5,061.6 | -207.5 (-4%) | -480.1 (-9%) |

Sources: IMPLAN 2010 and SWAP modeling results applied to IMPLAN 2010.

^a Coastal Southern California includes Santa Barbara, Los Angeles, Orange, Ventura and San Diego counties.

^b Not modeled in SWAP.

Table 3-3. Estimated direct effects (as total revenue losses) from water cost increase and water availability reduction for farming in inland Southern California^a (in 2008 dollars)

| IMPLAN Crop Group | Sector Output Losses | | |
|--|-----------------------------|----------------------------------|--|
| | Base Sector Output | Water Cost Increase (75%) | Water Availability Reduction (-25%) |
| | <i>Million \$/Year</i> | | |
| Cotton farming | 20.2 | -0.9 (-4%) | -4.3 (-21%) |
| Fruit farming | 767.0 | -8.4 (-1%) | -21.8 (-3%) |
| Vegetable and melon farming | 714.0 | -3.0 (-0.4%) | -22.2 (-3%) |
| Tree nut farming | 5.4 | 0.0 (0%) | -0.1 (-1%) |
| Greenhouse, nursery and floriculture production ^b | 310.6 | -1.3 (-0.4%) | -9.6 (-3%) |
| Oilseed, grain and other crop farming | 961.8 | -29.4 (-3%) | -183.9 (-19%) |
| Livestock and livestock products ^b | 1,230.1 | 0.0 (0%) | 0.0 (0%) |
| Total | 4,008.9 | -43.1 (-1%) | -241.9 (-6%) |

Sources: IMPLAN 2010 and SWAP modeling results applied to IMPLAN 2010.

^a Inland Southern California includes Riverside, San Bernardino and Imperial counties.

^b Not modeled in SWAP.

4. Broad Southern California economic effects of crop losses from irrigation cutbacks

The agricultural crop revenue losses implied by a reduction in the supply of irrigation water cause economy-wide multiplier effects and reduce economic activity across the region. We estimate these impacts by introducing the direct farm impacts into the IMPLAN model to simulate regional economic effects beyond farming.

The model estimates effects of a higher water cost or water cutbacks on regional employment, value added, and value of output. Loss of value of output is the total economic activity lost in the form of gross revenue or incomes each year. Loss of employment is jobs that are not available each year in the local region. Value added is the value of output (or sales) minus non-labor business expenses (that is, intermediate inter-sector purchases). Value added includes employee compensation, proprietary income and indirect business taxes. Value added is a primary measure of the value of the economic activity in a region as used, for example, in the concept of Gross Domestic Product (GDP).

We report three classifications of the impacts of water cost increases and quantity cutbacks. First, “Direct Effects” are the farming impacts to which multipliers are applied in the economy-wide analysis within the IMPLAN model. Second, “Indirect Effects” show the impact of local industries buying goods and services from other local industries. The cycle of spending works its way backward through the supply chain. These effects show how a reduction in farm activity reduces other economic activities because farms buy less from other local industries and because there are few goods and services applied locally to farm output as it moves through the marketing chain. Finally, “Induced Effects” are the responses by the Southern California economy to the reduction in farm output and economic activity that occurs through re-spending of income received by farmers, landlords, employees and other recipients of farm value added. The IMPLAN model framework recognizes that labor income recirculates through the household spending patterns causing further local economic activity.

4.1 Broad economy-wide effects of increasing water costs for Southern California agriculture

Table 4-1 shows the broad economic effects of the 75 percent irrigation water cost increase described above for employment, labor income, value added, and value of output. The water cost increase of 75 percent causes a direct revenue loss to all Southern California agriculture of \$251 million. We learn from the economy-wide model that the direct loss of employment is 1,221 jobs and the associated loss of value added is about \$126 million.

Indirect and induced effects together account for the loss of another 2,530 jobs, \$186 million of value added, and \$308 million of economic output. Thus, total output loss is about \$558 million, with value added loss of about \$313 million and total employment loss of 3,751 jobs.

Table 4-1. Total economic impacts of a 75 percent increase in water costs for affected crop groups in Southern California (in 2010 dollars)

| Impact Type | Employment | Value Added | Output |
|----------------------------|-------------------|--------------------|-------------------|
| | <i>Jobs</i> | | <i>Million \$</i> |
| Direct Effect ^a | -1,221 | -126.4 | -250.5 |
| Indirect Effect | -1,243 | -76.1 | -127.9 |
| Induced Effect | -1,287 | -110.1 | -179.8 |
| Total Effect | -3,751 | -312.6 | -558.2 |

Source: Author calculations using IMPLAN 2010.

^a The sum of coastal and inland direct output losses add to the total Southern California direct output losses in Tables 4-1 and 4-4. However, because IMPLAN bases its regional employment and value added effects on the ratios of jobs to revenue and value added to revenue, which differ by region, coastal and inland effects will not sum to total Southern California direct effects on employment and value added.

The impacts of increasing water costs differ between the coastal and inland counties of Southern California. Table 4-2 shows the impacts of higher water costs in the coastal area of Southern California and Table 4-3 shows impacts in the inland area. Along the coast, higher water costs result in total economy-wide losses of 3,348 jobs per year, \$265 million in value added and \$459 million in output. Induced effects on the coastal economy are greater than indirect effects, because agriculture represents a small share of the total economy in these highly populated and urbanized counties and thus has relatively little effect on other regional industries.

In contrast, indirect effects are higher than induced effects for the inland areas of Southern California, since agriculture is a significant player in their economic activities. Increased

water costs in the inland counties result in annual losses of 401 jobs, \$35 million in value added and \$74 million in output. Note that the induced and indirect effects in Southern California as a whole (Table 4-1) are larger than the sum of these effects for each sub-region because the analysis in Table 4-1 includes jobs and other impacts that spill across the sub-regions.

Table 4-2. Total economic impacts of a 75 percent increase in water costs for affected crop groups in coastal Southern California^a (in 2010 dollars)

| Impact Type | Employment | Value Added | Output |
|---------------------|-------------------|--------------------|-------------------|
| | <i>Jobs</i> | | <i>Million \$</i> |
| Direct Effect | -1,284 | -110.4 | -207.5 |
| Indirect Effect | -972 | -59.2 | -98.3 |
| Induced Effect | -1,093 | -95.0 | -153.6 |
| Total Effect | -3,348 | -264.6 | -459.4 |

Source: Author calculations using IMPLAN 2010.

^a Coastal Southern California includes Santa Barbara, Los Angeles, Orange, Ventura and San Diego counties.

Table 4-3. Total economic impacts of a 75 percent increase in water costs for affected crop groups in inland Southern California^a (in 2010 dollars)

| Impact Type | Employment | Value Added | Output |
|---------------------|-------------------|--------------------|-------------------|
| | <i>Jobs</i> | | <i>Million \$</i> |
| Direct Effect | -119 | -16.1 | -43.1 |
| Indirect Effect | -169 | -10.9 | -17.4 |
| Induced Effect | -113 | -8.0 | -13.1 |
| Total Effect | -401 | -35.0 | -73.5 |

Source: Author calculations using IMPLAN 2010.

^aInland Southern California includes Riverside, San Bernardino and Imperial counties.

4.2 Broad economy-wide effects of reducing water availability for agriculture

The effects of cutting water availability by 25 percent are shown in Table 4-4. The direct effects of the cut in irrigation water availability, derived from the third column of Table 3-1, are about \$722 million in output loss as shown in the top row of the third column of Table 4-4. Direct effects also include losses of \$342 million in value added and 3,161 jobs. The indirect and induced effects together triple the job loss, so that the total job loss is 9,963. Total loss in value added in Southern California is about \$866 million and the overall loss in output for the economy of Southern California is \$1.59 billion. The indirect and induced effects together more than double the direct monetary loss from the reduction in water available to farming.

Table 4-4. Total economic impacts of a 25 percent decrease in water availability for affected crop groups in Southern California (in 2008 dollars)

| Impact Type | Employment | Value Added | Output |
|---------------------|-------------------|--------------------|-------------------|
| | <i>Jobs</i> | | <i>Million \$</i> |
| Direct Effect | -3,161 | -342.4 | -722.0 |
| Indirect Effect | -3,337 | -227.4 | -382.8 |
| Induced Effect | -3,465 | -296.4 | -484.1 |
| Total Effect | -9,963 | -866.1 | -1,588.9 |

Source: Author calculations using IMPLAN 2010.

A 25 percent decrease in water availability for coastal agriculture alone causes economy-wide losses of 7,457 jobs, \$607 million in value added and \$1.05 billion in output per year (Table 4-5). These losses are between 2.5 and 3.5 times greater than the losses due to water cuts in the inland counties (Table 4-6). Inland total economic losses due to less water availability include 2,192 jobs, \$192 million in value added and \$412 million in output. About 30 percent of the inland jobs lost are direct effects. Almost 60 percent of inland lost value of output is the direct effect of farming. Induced and indirect effects in Southern California as a whole (Table 4-4) are larger than the sum of these effects for each sub-region because the analysis in 4-4 includes jobs and other impacts that spill across the sub-regions.

Table 4-5. Total economic impacts of 25 percent decrease in water availability for affected crop groups in coastal Southern California^a (in 2010 dollars)

| Impact Type | Employment | Value Added | Output |
|---------------------|-------------------|--------------------|-------------------|
| | <i>Jobs</i> | | <i>Million \$</i> |
| Direct Effect | -2,908 | -255.8 | -480.1 |
| Indirect Effect | -2,056 | -134.4 | -223.5 |
| Induced Effect | -2,493 | -216.7 | -350.5 |
| Total Effect | -7,457 | -606.9 | -1,054.0 |

Source: Author calculations using IMPLAN 2010.

^aCoastal Southern California includes Santa Barbara, Los Angeles, Orange, Ventura and San Diego counties.

Table 4-6. Total economic impacts of a 25 percent decrease in water availability for affected crop groups in inland Southern California^a (in 2010 dollars)

| Impact Type | Employment | Value Added | Output |
|---------------------|-------------------|--------------------|-------------------|
| | <i>Jobs</i> | | <i>Million \$</i> |
| Direct Effect | -651 | -86.4 | -241.9 |
| Indirect Effect | -935 | -62.9 | -99.7 |
| Induced Effect | -606 | -43.0 | -70.2 |
| Total Effect | -2,192 | -192.3 | -411.9 |

Source: Author calculations using IMPLAN 2010.

^aInland Southern California includes Riverside, San Bernardino and Imperial counties.

5. Effects beyond those covered in the formal models

Changes to water supply directly affect more than just crop farming. Irrigation water does not directly affect the budget for livestock and dairy operations, but water is nonetheless a critical input for the animal industry. This section also considers impacts on water districts and agencies that distribute irrigation water to farmers. The agencies and districts experience revenue gains or losses when irrigation rates increase or when water supply is reduced.

5.1 Effects of reduced water supply on livestock and dairy industries

Our formal modeling is limited to major crops because we lack the data to incorporate some commodities in the SWAP model, especially livestock products. Although the SWAP model does not allow us to quantify the direct effects of irrigation water cuts and higher water costs on the Southern California beef, poultry and dairy industries, we note that in addition to added cost of cleaning, maintenance and watering animals, a cutback in water use for crop agriculture reduces production of forage and other feeds. As a result, local input costs for dairy and livestock producers rise, hastening the long-term gradual shift of production out of Southern California.

5.2 Effect of reduced water supply on water district revenues

Most water management in California is local or regional. More than a thousand entities, including specialized and general-purpose local governments, water companies and other organizations, manage water in California (Hanak et al., 2011). For example, the Metropolitan Water District of Southern California (MWDSC) serves 19 million people and 5,200 square miles within six counties (Ventura, Los Angeles, San Bernardino, Orange, Riverside, and San Diego). With more than 25 member agencies, it is the largest among a few dozen water wholesalers in the state. MWDSC supplies water mostly to urban users, but also to some agricultural users in the six-county service area. The Imperial, Coachella, and Palo Verde irrigation districts are also examples of major entities that manage irrigation water within their respective boundaries.

A 25 percent cutback in water availability or a 75 percent increase in water costs for agriculture would affect irrigation district or agency revenues. The impacts on water revenues depend on the relationships between water use and cost increases. Water costs for irrigators and revenue data for Southern California districts are not readily available.

However, data for representative districts can be used to illustrate changes in individual irrigation district revenues as a result of the two scenarios modeled.

There are roughly 150 water agencies in Southern California, each with different water rates and fees for irrigation (ACWA, 2012). We selected the Imperial Irrigation District (IID), the Casitas Municipal Water District (CMWD) in Ventura, and the San Diego County Water Authority (SDCWA) to illustrate the impacts of the two irrigation water scenarios. The IID is a low-price inland water district in the far southeast of the state, the CMWD is a middle-price district in the coastal valleys of Ventura County, and the SDCWA is a high-price district along the San Diego County coast.

We estimate changes in district revenues from agricultural water deliveries using 2010 water rates, adopted budgets and financial statements. The SWAP model for Southern California provides farm output and water use responses to water supply reductions (see Tables 3-1, 3-2 and 3-3). If water availability decreases by 25 percent, holding water cost constant, irrigation districts will see a 25 percent decrease in revenues from agricultural water use. If water costs increase by 75 percent, inland counties reduce irrigation water use by an average of 10 percent, according to SWAP. This relationship translates to a water price elasticity of 0.14 for inland agricultural production. Given the 75 percent increase in water costs, coastal counties reduce irrigation water use by an average of 14 percent, yielding a coastal water price elasticity of 0.19. (These elasticities are within the range found in a recent meta-data analysis of water demand in agriculture by Schoengold, et al. 2006). Under the water cost increase scenario, irrigation districts gain revenue because the 75 percent increase in water rates—and therefore revenue—is greater than the 10 to 14 percent loss from decreased irrigation water use.

Recall that rates for water deliveries to agriculture may vary within and among districts, depending on available funding, water infrastructure, water source(s), the affected crop, and any water trading between farmers. Responses in the quantity of water demanded on-farm due to a 25 percent cut in availability or 75 percent water cost increase also depend on the crop, irrigation method, and region. In our calculations, we assume there is no increase in water cost when the quantity of water declines and that the 25 percent cut is uniform across districts. For the price-increase scenarios, we assume that water that is not demanded for irrigation within the district is not sold outside the district or to non-agricultural users and thus generates no revenue for the district.

The Imperial Irrigation District consumptive use water allocation is 3.1 MAF/year. Farmers use 2.5 MAF/year within the IID and the remainder is sold or used for groundwater banking. A 25 percent water availability cutback to agriculture within IID, assuming that water cost to irrigators stays constant, results in irrigation district revenue losses of 25 percent, or \$11.9 million per year. From the 2010 IID cost of \$19/acre-ft, an

agricultural water rate increase of 75 percent causes revenue gains of \$30.9 million per year. This gain accounts for a 10 percent fall in the quantity of irrigation water demanded due to the higher water cost, meaning that net gains to IID revenue are about 65 percent.

Ventura County contains three major water purveyors: the Calleguas Municipal Water District, United Water Conservation District, and Casitas Municipal Water District (CMWD). Calleguas largely serves urban water users at a current base supply cost of \$106/acre-ft, while United Water 2010 irrigation rates are relatively low at \$20 to \$38/acre-ft. We use the Casitas District as our illustration because its cost of water best reflects what is typical of tree crops and high revenue-per-acre crops in Ventura County. The CMWD is a small district serving its agricultural sector at 2010 rates ranging from \$256/acre-ft for gravity-fed water to \$371/acre-ft for pumped water. Total CMWD revenue from the 1,862 acre-feet of irrigation water consumed during the 2010 fiscal year was \$664,430, mostly from pumped water. For CMWD, a 25 percent cut to irrigation water sales reduces these revenues by about \$166,100. A water cost increase of 75 percent decreases the quantity of water demanded by 14 percent, resulting in revenue gains from water sales of roughly \$405,300 per year.

The San Diego County Water Authority is a member of the Southern California umbrella district, MWCD. Agricultural water rates in SDCWA were \$484 /acre-ft for untreated water and \$699/acre-ft for treated water in 2010. Recent reports from SDCWA indicate a sharp decline in agricultural water use, from 104 TAF/year in 2007 down to 54 TAF/year in 2011. Assuming that agriculture uses 54 TAF/year, a 25 percent cutback in water availability at the 2010 published rates causes SDCWA revenue losses ranging from \$6.5 to \$9.4 million dollars per year, depending on the proportion of treated versus untreated water sold. A 75 percent water cost increase, accounting for the effects of a corresponding 14 percent decrease in water use, results in revenue gains from water sales to agriculture that range from \$15.9 to \$23.0 million per year.

6. Concluding remarks

Southern California agriculture is large and diverse. Farming generates \$8.2 billion per year (18% of state agricultural production value), uses 2.8 million acres and generates about 41 thousand jobs in the eight counties analyzed in this study. Agriculture in Southern California is especially vulnerable to reductions in irrigation water because groundwater is not a significant potential substitute for surface water deliveries in many areas. Furthermore, since urban uses account for more water than agricultural uses in many areas, and since urban users are inflexible in their demands for water, agriculture is left with little recourse if water supplies are reduced to the region as a whole.

Changes in cost and availability of water for irrigated crops in Southern California affect farm output, employment and value added. Such water supply reductions also have large negative effects elsewhere in the economy. Water cost increases of 75 percent would result in about \$560 million in output losses per year and the loss of about 3,750 jobs. About 90 percent of those losses occur in the coastal counties, where water costs are already high and where irrigated agriculture generates substantial economic activity and employment. Cutbacks in the availability of irrigation water by 25 percent would result in even larger economic costs for agriculture and for the regional economy—output losses would be about \$1.59 billion and job losses about 9,960. These losses also occur primarily in the coastal counties.

We have quantified the economic effects in terms of lost output, employment and value added, but the contributions of agriculture to Southern California include more than just jobs and incomes. Water districts also stand to gain or lose millions of dollars in revenue when the water cost increases or quantity supplied falls. Agriculture contributes open space, visual amenities, fresh local food and a connection to the environment that is unique in the relatively urban areas of the region. So, while the numbers and multiplier effects we have calculated are large and important, they do not cover all the losses that would be suffered in Southern California in the face of irrigation water cutbacks.

References

- Agricultural and Resource Economics, University of California, Davis. 2012. Cost and Returns Studies. <http://coststudies.ucdavis.edu/>
- Association of California Water Agencies. 2012. ACWA Regions. <http://www.acwa.com/content/acwa-regions>
- Bartolomeo, E.S. 2011. *Economic Responses to Water Scarcity in Southern California*, Civil and Environmental Engineering. University of California: Davis, California, p. 115p.
- California Department of Water Resources, Integrated Water Management. 2009. *California Water Plan Update 2009. Bulletin 160-09 Department of Water Resources*. <http://www.waterplan.water.ca.gov/cwpu2009/index.cfm>
- Calleguas Municipal Water District. 2012. Water Rates and Charges. http://www.calleguas.com/water_rates.htm
- Casitas Municipal Water District. 2012. Finance. <http://www.casitaswater.org/lower.php?url=finance>
- Hanak, E., Lund, J.R., Dinar, A., Gray, B., Howitt, R., Mount, J., Moyle, P., Thompson, B. 2011. *Managing California Water from Conflict to Reconciliation*. PPIC Press, San Francisco, CA.
- Imperial Irrigation District. 2012. Agriculture Customers. <http://www.iid.com/index.aspx?page=151>
- Lee, H., Sumner D.A. and Howitt R. 1999. *Economic Impacts of Irrigation Water Cuts in the Sacramento Valley*. UC Agricultural Issues Center. <http://aic.ucdavis.edu/publications/oldanrpubs/econimpactirrig.pdf>
- The Metropolitan Water District of Southern California. 2012. About MWD. <http://www.mwdh2o.com/mwdh2o/pages/about/about01.html>
- Pulido-Velazquez, M., Jenkins, M.W., Lund, J.R. 2004. "Economic values for conjunctive use and water banking in southern California." *Water Resources Research* 40(3) 15.
- San Diego County Water Authority. 2012. Water Management. <http://www.sdcwa.org/water-management>
- Schoengold, K., Sunding, D.L., Moreno, G. 2006. "Price elasticity reconsidered: Panel estimation of an agricultural water demand function." *Papers in Natural Resources*. Paper 27. <http://digitalcommons.unl.edu/natrespapers/27/>

U.S. Department of Agriculture, National Agricultural Statistics Service, California Field Office. 2011. California County Agricultural Commissioners' Data, 2010.
http://www.nass.usda.gov/Statistics_by_State/California/Publications/AgComm/Detail/index.asp

United Water Conservation District. 2012. Financial Reports.
<http://www.unitedwater.org/financial-reports.html>

Vergati, J.A. and Sumner, D.A. 2012. *Contributions of Agriculture to Employment and the Economy in Southern California*. University of California Agricultural Issues Center.
<http://aic.ucdavis.edu>