Water, Climate Change, and California Agriculture

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Climate change may modify the current California water supply system. Analysis of a 2050 climate change scenario shows that despite reductions in irrigated area and net water use, California agriculture can continue to grow in revenue value and employment.

California agriculture is shaped by water supplies that depend on its current climate, but future projections based on global climate circulation models show an increase in average temperature. This change will have a significant impact on California's water resources and the industries that they depend on, none greater than irrigated agriculture that uses over 80% of the developed water in California. It is no exaggeration to say that California agriculture runs on water delivered in the right quantity, quality, and location.

The characteristics of a Mediterranean climate—cool, wet winters and warm, dry summers—and the geographic distribution of California's water supply require a water storage and distribution system that covers the entire state. The current storage and transport system, which delivers California's water from the relatively lush northern half of the state to the San Joaquin Valley and arid southern coastal regions, is essential to supplying water to the right place at the right time.

Increases in the ambient temperature of California will change water supply in three ways. First, water runoff in the wet areas will be reduced. Second, the amount of water stored in the snow and ice pack in the mountains will be significantly depleted. Third, the increased temperatures and CO_2 will result in an increase in the evapotranspiration rate of many crops.

Climate Change Impacts

Predicted changes in California precipitation from climate change are much less dramatic and also less certain than temperature changes. The best consensus is that the mean precipitation will not change greatly, but the distribution of precipitation will shift backwards in the year by at least one month and precipitation will probably be more volatile. This means that the spring runoff will come warmer and earlier, which in turn means that dams will have to allow a greater empty reserve for flood control to achieve the same degree of reduction in flood risk that currently exists.

In addition, the warmer air temperature will mean that there is less storage, and the snowpack will melt faster and earlier. Combining these factors results in a significant reduction in the inflows into the California water storage system.

The analytic results in this article are drawn from a multidisciplinary study by Medellin-Azuara et al., 2012. The study used 35-year projections of climate change results to 2050, based on a climate model from the Geophysical Fluid Dynamics Laboratory. Under a high-emissions scenario (GFDL A2), the model predicted an average 2°C temperature increase by 2050, and a 4.5°C increase by the end of the century. This climate scenario predicts a significantly higher rise in temperature than many other global climate models; accordingly, these results should be regarded as an upper bound on the impact of water resources.

The effect of earlier and reduced runoff can be partially mitigated by reoperation of the California storage and water transport system. Table 1 shows the percent reduction in water deliveries by sector and region. The effect on deliveries varies by sector and region, but combining climate change and water operation models, the estimate is that there will be a 21% reduction in water deliveries by the year 2050. It is important to note that these cuts are after reoperation and potential water market trades between regions and sectors have been optimized.

The climate change-induced increases in CO_2, temperature, and heat stress will have different effects on yields of California crops, depending on the type of crop and the region. Generally, crop yields are predicted to decrease, particularly those in

Table 1. Percent Reduction in California Water Supplies by 2050

	Percent Reduction		
Region	Agriculture	Urban	Total
Sacramento	24.3	0.1	19.1
San Joaquin	22.5	0.0	17.6
Tulare	15.9	0.0	13.5
Southern California	25.9	1.12	8.9
Total	21.0	0.7	14.0

Source: Medellin-Azuara et al., 2012

The three columns are percentages with respect to different quantities for each sector, they are completely different and should not sum up since agriculture and urban have very different supply quantities. They are designed to show the percent reduction by region, sector, and total—nothing else.

Table 2. Climate-Induced Yield Change (%) by 2050		
Crop Groups	Sacramento	San Joaquin
Alfalfa	4.9	7.5
Citrus	1.77	-18.4
Corn	-2.7	-2.5
Cotton	0.0	-5.5
Field Crops	-1.9	-3.7
Grain	-4.8	-1.4
Orchard	-9.0	-9.0
Pasture	5.0	5.0
Grapes	-6.0	-6.0
Rice	0.8	-2.8
Tomatoes	2.4	1.1
Truck Crops	-11.0	-11.0

Source: Medellin-Azuara et al., 2012

Southern California. The exceptions are alfalfa, pasture, and tomatoes whose yields are predicted to increase. Table 2 shows the expected effect on crop yields due to climate-induced changes in the growing environment.

Modeling California Agriculture in 2050

Three different scenarios were used to estimate the effects of climate change: a base model for 2005, a model with historical climate in 2050 (no climate change), and a model with warm-dry climate change (GFDL A2) in 2050. The base model is calibrated to 2005 conditions and is used as a reference point and a basis for extrapolation to later years.

The historical 2050 model represents California agriculture in 2050 in the absence of climate change, but incorporates shifts in market demand for California crops due to changed population and incomes, and technical changes in crop production. The warm-dry model represents agriculture in 2050 with the effects of climate change. The model results measure changes that occur with or without climate change, and those that only occur under climate change.

California agriculture will be changed significantly by 2050, with or without climate change, due to several driving forces. First, reduced water availability due to increases in urban water demand and currently unsustainable levels of groundwater pumping. Second, the expansion of urban land use in agricultural regions will divert both land and water from agriculture. Third, the current rate of technical improvement in crops yields will very likely slow down, but will still be significant.

Water shortages are the key variable by which climate change will reduce the growth of California agriculture.

Changes in urban land use, which affects the potential footprint for agriculture in the future, are derived from land use projections by Landis and Reilly for the year 2050. Technological improvements, as represented by yield increases, have been an important driving force for the recent trends in agricultural production. Based on Brunke et al., these effects incorporate yield changes as a result of technological improvement. Finally, tastes and preferences are held constant, but increasing population and income are translated into shifts in the demand for crops, which differ greatly between California specialty crops and "global" commodity crops.

In addition to the effect of changes in production technology, crop yields are expected to change in response to climate change. The estimates in Table 2 are based on a review of literature, and project expected changes in yield that are based on the climate-change scenario (see "Further Reading"). The second important modification caused by climate change is changing water supply and availability. The study by Medellin-Azuara et al. used the CALVIN water policy model to estimate changes in water deliveries for agriculture. These estimates are then incorporated into the agricultural economic SWAP model to estimate resulting changes in regional cropping areas, revenues, and returns to land and management. (Howitt et al., 2012).

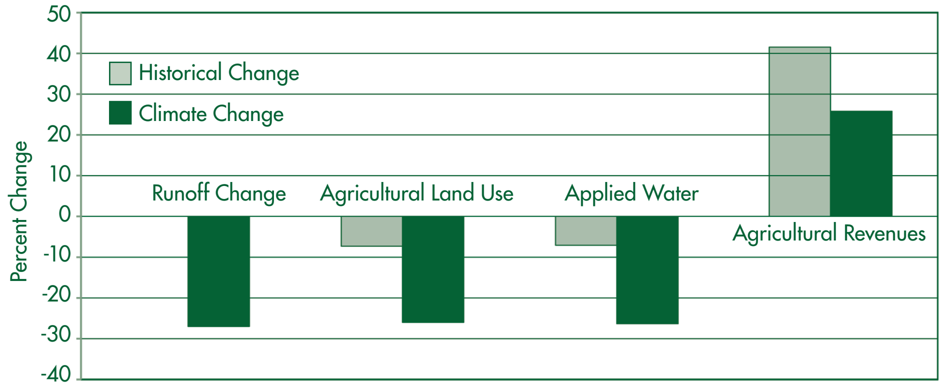
The SWAP model includes the shifts in the demand for crops projected to 2050, as discussed earlier. When combined with results from the biophysical models (which measure the effect of climate change on yields), the results show the importance of integrating and modeling the extent of adaptations of bio-economic systems to climate change. Since agricultural production systems are primarily driven by economic incentives, they can be expected to adjust and adapt by changing irrigation methods at the field level, though better systems or stress irrigation, and also by changing the crop mix on the farm to maximize returns from the available water. The results show such adaptations for irrigated agriculture in California.

Model Results

The model results show that irrigated land area in California will diminish, with or without climate change. The estimated reductions in irrigated agricultural area between 2005 and 2050 are 7.3% without climate change, and 26% under the climate-change scenario. Water runoff to agriculture is significantly reduced by 27%; however, after optimal reoperation of California's network dams and canals, coupled with a hypothetical open market for water between regions and sectors, the reduction in agricultural water deliveries is 7% without climate change, and 21% under the climate change scenario.

Despite this reduction in both land area and applied water, California's irrigated agricultural industry shows substantial growth in productivity and revenue, both with and without climate change. Without curtailments of the water supply and yield reductions, the model predicts that agricultural revenue

Figure 1. Percent Change in Agricultural Land Area, Water, and Revenue



Source: Medellin-Azuara et al., 2012

will grow in real terms by 40% by 2050. Climate change certainly reduces the rate of growth of the industry, but it will still grow in terms of revenue, profitability, and employment by 28% by 2050.

Figure 1 illustrates this sequential adjustment process of biotechnological and economic change within the industry. The systematic adjustments made throughout productive and economic parts of bio-economic systems show the ability of California agriculture to grow, despite a 27% reduction in water runoff. The growth in revenue is slower than the projections based on historical conditions but with climate change, the industry is still able to grow by 12% in real terms over the next 35 years.

Conclusions

The impacts of climate change on California water supplies and growing seasonal temperature mean that yields will be reduced in both perennial and annual crops—with the exception of fodder crops, which will show small increases in yields. Water shortages are the key variable by which climate change will reduce the growth of California agriculture. Adaptation to climate change by improved production technology and resource management can partially offset the economic impacts of resource reductions. The models that underlie this study show that the industry will continue to grow in both revenue and employment, despite significant reductions in land area and water use. This result is predicated on the assumptions that the demand for California specialty fruit and vegetable crops will continue to grow in a similar manner as it has in the past.

Suggested Citation:

Howitt, R.E., 2014. "Water, Climate Change, and California Agriculture." *ARE Update* 18(1):13-15. University of California Giannini Foundation of Agricultural Economics.

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Further Reading

Adams, R.M., J. Wu, and L.L. Houston, 2003. "Climate Change and California, Appendix IX: The Effects of Climate Change on Yields and Water Use of Major California Crops," California Energy Commission. Public Interest Energy Research (PIER), Sacramento, CA.

Brunke, H., D. Sumner, and R.E. Howitt, 2004. "Future Food Production and Consumptionin California Under Alternative Scenarios," Agricultural Issues Center, University of California, Davis, CA.

Howitt, R.E., J. Medellín-Azuara, D. MacEwan, and J.R. Lund, 2012. "Calibrating Disaggregate Economic Models of Agricultural Production and Water Management." *Environmental Modeling and Software* 38: 244-258.

Landis, J.D. and M. Reilly, 2002. How "We Will Grow: Baseline Projections of California's Urban Footprint Through the Year 2100. Project Completion Report,"Department of City and Regional Planning, Institute of Urban and Regional Development, University of California, Berkeley., Berkeley, CA. www-iurd.ced.berkeley.edu/pub/WP-2003-04-screen.pdf.

Lee, J., S. De Gryze, and J. Six, 2009. "Effect of Climate Change on Field Crop Production in the Central Valley of California," California Energy Commission, Public Interest Energy Research (PIER), Sacramento, California, p. 26. www.energy.ca.gov/2009publications/CEC-500-2009-041/CEC-500-2009-041-D.PDF.

Lobell, D.B., K.N. Cahill, and C.B. Field, 2007. "Historical Effects of Temperature and Precipitation on California Crop Yields," *Climatic Change,* 81: 187-203.

Medellin-Azuara, J., R.E. Howitt, D.M. MacEwan, and J.R. Lund, 2012. "Economic Impact of Agricultural Climate Related Yield Changes in California." *Climatic Change,* 109(1): 387-405.