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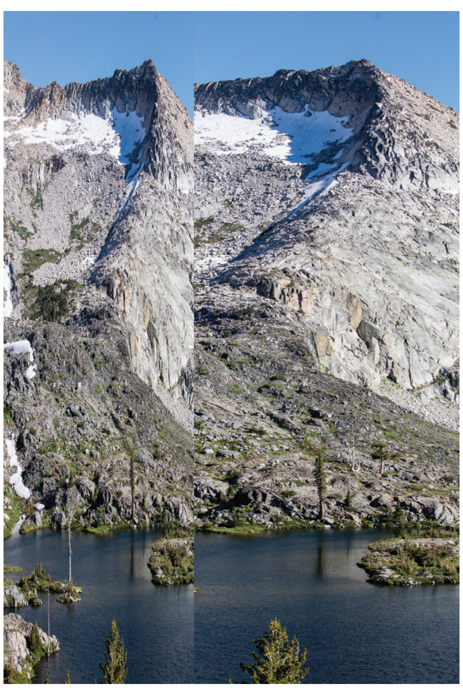
ALSO IN THIS ISSUE

Climate Change and California's Water Supply: How Can We Adapt?

Ellen M. Bruno and Katrina Jessoe

Climate change is expected to alter water supplies in California fundamentally. The state must find ways to adapt. This article explores potential adaptation strategies and the role that water markets can play in mitigating some of the economic costs of climate change.



Warming temperatures imply that less precipitation will fall as snow, snowpack will melt earlier, and increased evaporation will reduce soil moisture and surface water availability.

Climate Change Impacts to Water Supplies

Water management in California will face growing challenges due to climate change. Climate change models predict changes to the timing, variability, and form of precipitation in California. These shifts in water supplies will impact both the quantity and quality of water, and have far-reaching impacts on agriculture, urban users, industry, rural communities, and ecosystems.

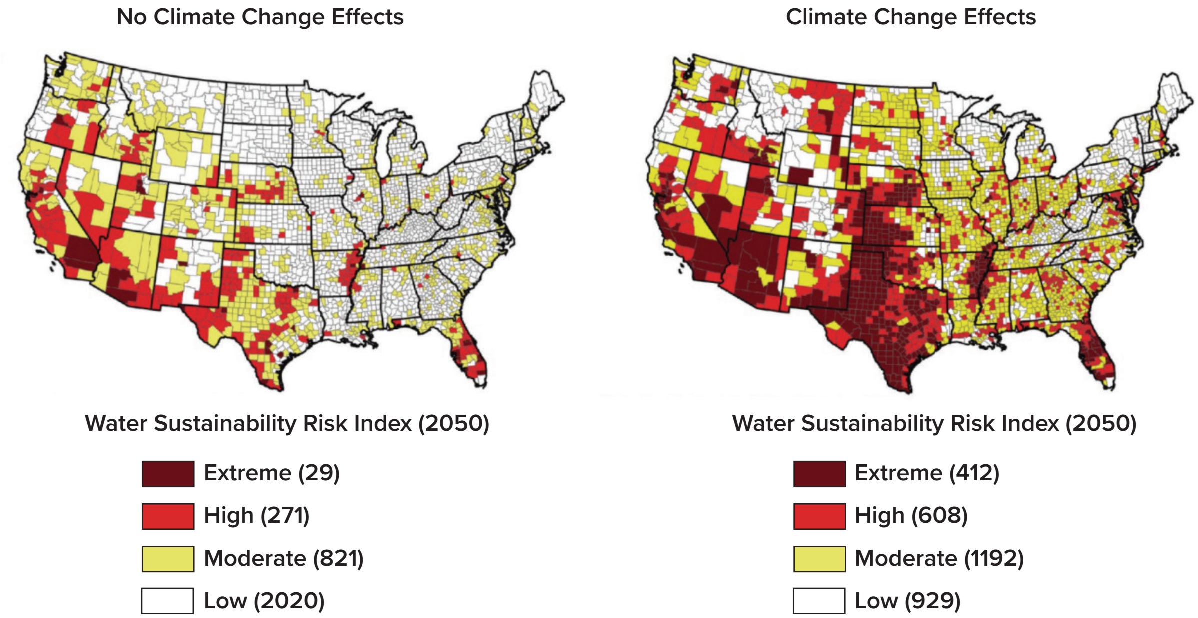
Climate change will impact water supplies through warming temperatures and changes in precipitation patterns. Warming temperatures imply that less precipitation will fall as snow, the snowpack will melt earlier, and increased evaporation will reduce soil moisture and surface water availability. A shift in precipitation from snow to rain will reduce the state's capacity to manage water stored in the Sierra Nevada and southern Cascades snowpack.

Warming temperatures will also influence when the snowpack melts, and subsequently when water can be accessed. More water will be released as outflow in the Sacramento-San Joaquin Delta (flood water to the ocean), and less will be available to agriculture and other uses later in the year. Sea-level rise will further complicate movement of water through the Delta.

Changes in precipitation patterns project increased variability in interdecadal precipitation, with both droughts and floods becoming more frequent and more severe. Groundwater overdraft may also be an indirect consequence of climate change if users compensate for surface water shortages during droughts with increased groundwater pumping.

Due to climate change, some agricultural regions in California could face water shortages. Figure 1 (on page 2) illustrates changes in a water supply sustainability risk index under different future scenarios. The figure on the left corresponds to 20th-century conditions, i.e., 1934–2005, and the figure on the right corresponds to conditions under one projected climate-change scenario. It makes clear that a large swath of the southwestern U.S. could experience large changes to the sustainability of water supplies by 2050.

Figure 1. Projected Declines in Water Supplies



Source: Roy et al. 2012 "Projecting Water Withdrawal and Supply for Future Decades in the U.S. under Climate Change Scenarios" *Environmental Science & Technology.* Volume 46: 2545–2556. DOI: 10.1021/es2030774.

Potential Adaptation Strategies

There are many ways to adapt to changing water supplies. The storage of water in aquifers, increased investment in new water supplies, and improvements in water efficiency present some oft-discussed strategies. Increased groundwater recharge during wet periods presents one avenue to adjust to the storage lost from the reduced Sierra Nevada snowpack.

Alternative water supplies including desalinization and recycled water may buffer against water shortages experienced during times of drought. Improvements in irrigation, urban water, and commercial water efficiency may also lessen the costs from disruptions in available water supplies. Improved storage and alternative water supplies will likely play important roles in California's water-management response to climate change.

An additional and promising adaptation strategy to climate change is how California chooses to manage and allocate existing water supplies. Improvements in the allocation mechanism of current water supplies could enhance total economic surplus, and offset some of the losses from reduced water supplies during droughts. Water trading is an instrument that would allow for the reallocation of water supplies, improve upon the current allocation of water resources, and potentially soften the costs of climate change to California water users.

Water Markets

Water markets may substantially mitigate the economic costs of drought and climate change. Using Riverside County in Southern California as a case study, we evaluate the economic gains of water trading under several potential reductions to the water supply. Riverside County presents a unique setting to study the potential of water markets, since it is home to both a large urban population and an agriculturally productive region; also, many urban and agricultural users rely on the same primary groundwater source for their water supply. Focusing on the gains from trade within a single political county where diverse users share a water source overcomes the difficult task of accounting for the political, legal, and physical impediments commonly involved with water trading.

Water trading would enable the reallocation of water among users that differ in their marginal valuations of water. Those with a higher willingness-to-pay for additional acre-feet of water would buy from those with a lower willingness-to-pay, generating an increase in economic welfare for both parties.

Substantial gains from the reallocation of water resources could occur in Riverside County because of distortions in water pricing across agricultural and urban users, and because of differences in how these users respond to changes in water prices. In Riverside County, the per-unit price of water for a residential household is roughly four times greater than that paid by the average agricultural user. The implication of these price differences is that significant gains from the reallocation of water resources could be achieved, even in the absence of water-supply curtailments.

Gains from trade also occur because agricultural and urban water users differ in their responsiveness to changes in the volumetric price of water. A typical hurdle in measuring the gains from trade is obtaining an accurate estimate of agricultural users' response to price changes. We estimate the price elasticity of groundwater demand in an agricultural setting—the Coachella Valley Water District—where users face one of three geographically determined volumetric prices for groundwater. Using rich, monthly data on well-level groundwater extraction that spans 18 years, we find that a 10% increase in prices causes almost a 2% decrease in agricultural groundwater pumping.

Our simulation, which estimates water demand curves for agricultural and urban users, reports substantial increases to economic welfare from the establishment of water markets that allow for trading between the urban and agricultural sectors. Simply opening up existing water supplies to trade would lead to a reallocation of water, with 16% of water use moving from the agricultural to urban sector. The reallocation of water to those with a higher willingness-to-pay would increase both agricultural and urban welfare.

To further our understanding of the role that water markets could play in climate change adaptation, we also simulate the gains from trade under a range of curtailments to baseline water-supplies. In each scenario, we impose a percent reduction in total baseline water use and apply this percentage uniformly across urban and agricultural users. We perform this simulation for conservation targets that range from 5% to 30% of 2016 water use in (two water utilities serving) Riverside County. This reduction translates into 14,000 to 86,000 acre-feet of water, and fits within the climate-related water-supply reductions projected in California's fourth climate change assessment.

After introducing this abatement policy, we then allow trading to occur across the two user groups, and model the equilibrium market price, the traded quantity of water, and the fraction of total abatement performed by the agricultural sector. We also compare the costs of meeting this conservation mandate with trade to the costs incurred under a uniform standard (i.e., when trading is prohibited).

Our simulation highlights that for a range of water-supply curtailments, the agricultural sector performs all of the mandated water conservation and urban water users comply with the conservation target by purchasing water from the agricultural sector. The market price for a traded acre-foot of water rises as water-supply curtailments become more extreme and water becomes increasingly scarce. Across the range of curtailment scenarios, the gains from trade relative to a uniform standard for water abatement are large, remaining over 70% in all scenarios. We conclude that meaningful savings can occur if water users can respond to water-supply curtailments through trade.

Conclusion

Climate change will fundamentally alter the quantity, quality, and timing of available water supplies in California. As climate change shifts the availability, storage, and form of water supplies in California, water management practices will need to adapt. Water markets will allow for the reallocation of water to the highest-valued uses, and in doing so may reduce the economic costs of climate change. Our research quantifies the extent to which water markets will reduce the costs from reductions in existing water supplies relative to a uniform standard, and highlights significant cost savings from the implementation of markets. We conclude that water markets present a promising adaptation strategy to drought and climate change.

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Authors' Bios

Ellen Bruno is an assistant UC Cooperative Extension specialist in the Department of Agricultural and Resource Economics at UC Berkeley. She can be contacted by email at ebruno@berkeley.edu. Katrina Jessoe is an associate professor in the Department of Agricultural and Resource Economics at UC Davis. She can be contacted by email at kkjessoe@ucdavis.edu.

For additional information, the authors recommend:

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