Sustaining farms and groundwater

How can California continue to grow food and support farming communities, while protecting groundwater for the future?

INTRO

Farms need water to grow crops and stay economically viable. Agricultural water comes primarily from surface water diverted from rivers and reservoirs, and from groundwater pumped from aquifers. These sources are closely connected. When surface water becomes limited, farmers often rely more heavily on groundwater, particularly during droughts or periods of high demand. Water from rivers and irrigation can percolate through the soil and help recharge aquifers. But if groundwater pumping exceeds recharge over time, groundwater overdraft occurs, putting farms, drinking water supplies, and ecosystems at risk.

WHY THIS MATTERS

California grows a large share of the nation’s fruits, nuts, and vegetables. Farming supports jobs, local economies, and food systems across the country. But agriculture is also the largest water user in the state.

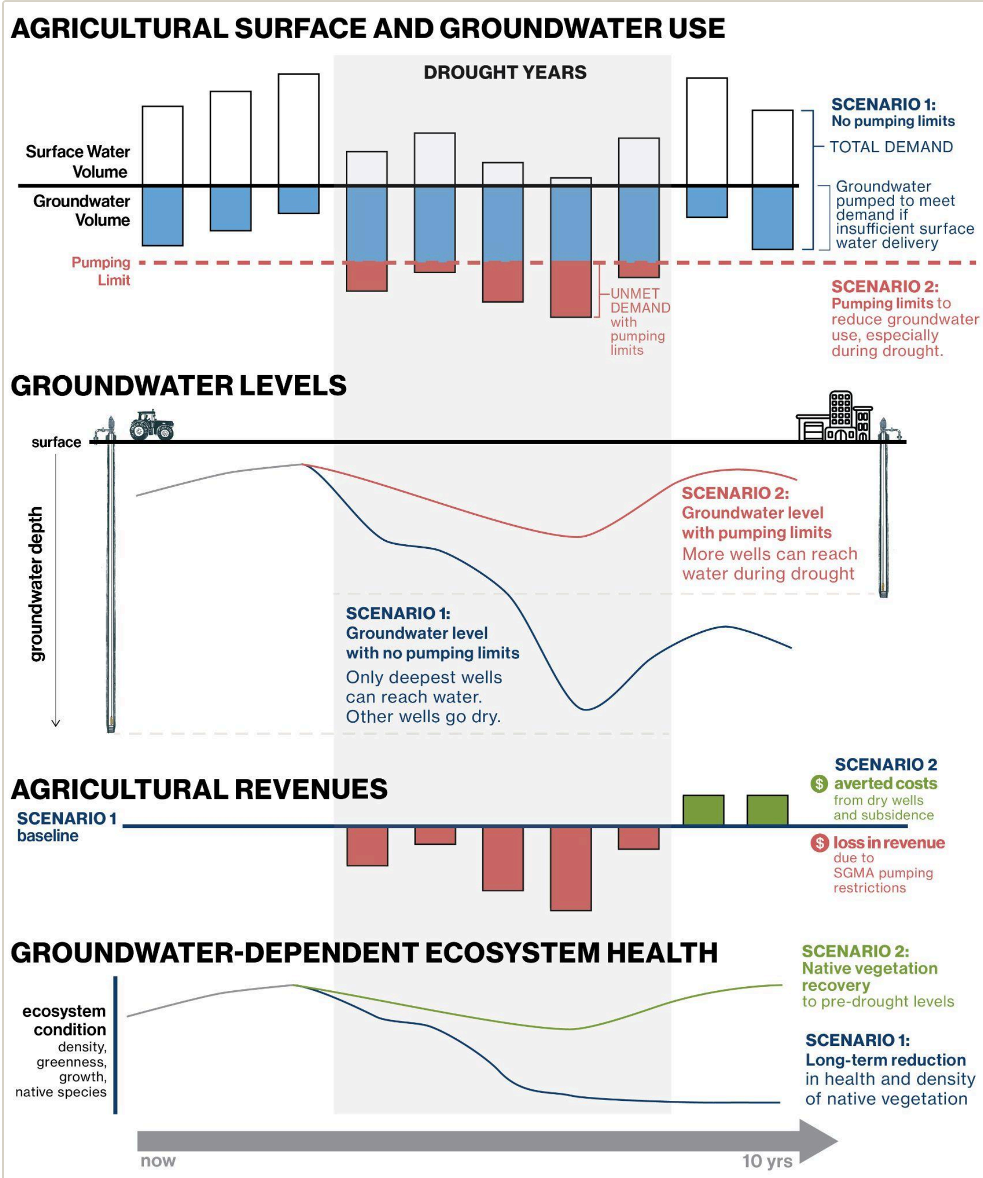
Over time, heavy groundwater pumping can lower groundwater tables. When pumping persistently exceeds recharge, groundwater overdraft can cause wells to go dry, increase pumping costs, contribute to land subsidence, and reduce groundwater contributions to rivers and freshwater ecosystems. These problems have been particularly acute in parts of the San Joaquin Valley. At the same time, climate change is reducing snowpack and increasing drought intensity, which makes surface water supplies less reliable. These changes make the long-term sustainability of groundwater increasingly important.

California's Sustainable Groundwater Management Act (SGMA) requires groundwater basins to achieve long-term balance between pumping and recharge. Meeting SGMA requirements may involve reducing pumping alongside other changes in agricultural water and land management. Understanding how surface water deliveries, groundwater use, and agricultural production change as groundwater restrictions are put in place is essential for planning for a sustainable agricultural future.

Relationships between agricultural water use, groundwater levels, and agricultural revenues, and groundwater-dependent ecosystems over time under two hypothetical scenarios.

When no restrictions on groundwater pumping are imposed (Scenario 1), groundwater use increases during drought, causing declines in groundwater levels. With reductions in groundwater use (Scenario 2), groundwater can still help mitigate agricultural losses during the worst drought years, while groundwater levels remain more stable over the long term. However, reduced access to groundwater during drought can lead to unmet agricultural water demand and lower agricultural revenues.

Over the longer term, maintaining more sustainable groundwater levels can reduce problems associated with overdraft, including land subsidence, dry wells, and reductions in groundwater contributions to surface waters. Groundwater-dependent ecosystems can also benefit, as more stable groundwater levels can help sustain native vegetation and support recovery following drought.



WHAT THIS WATER ISSUE FOCUSES ON

Groundwater sustainability and agricultural adaptation

As groundwater management requirements are implemented, some regions may need to reduce pumping. Farmers may respond by fallowing land, changing crops, improving irrigation efficiency, developing or shifting to alternative water supplies where alternatives are available, or making other long-term changes to farming operations. These changes can affect agricultural production, farm employment, and local economies, particularly when reductions persist over multiple years.

Surface water and groundwater as a connected system

Surface water and groundwater are connected parts of California's water system, but access to each source varies considerably across agricultural regions and individual farms. Where groundwater is available, pumping often increases when surface water deliveries decline. Over time, increased pumping can lead to declining groundwater levels.

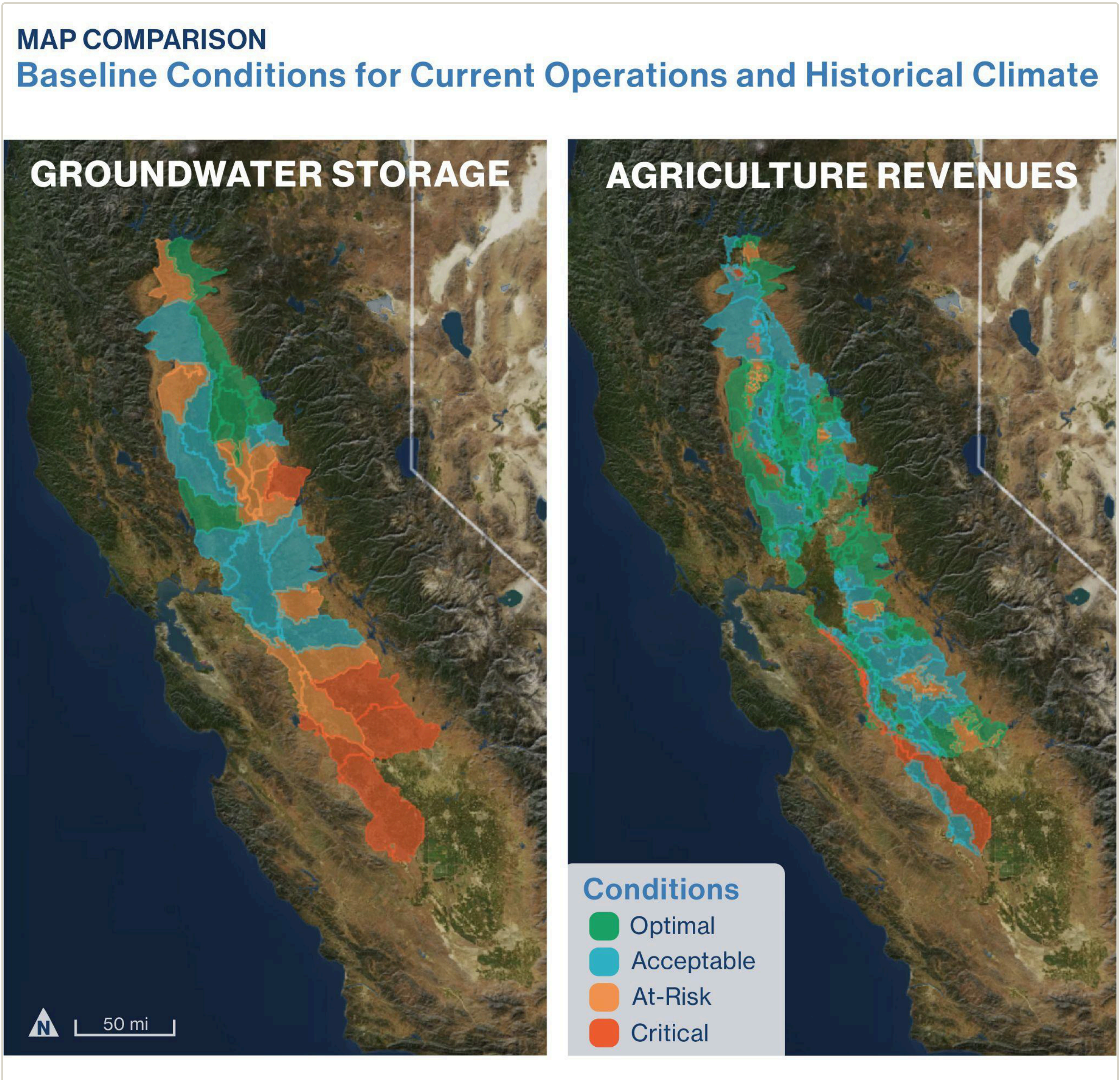
System connections and trade-offs

Decisions about groundwater, land use, and surface water deliveries affect multiple parts of the system. Reducing groundwater pumping may increase pressure on surface water supplies. Changes in one region may shift demands or impacts to other regions or water sources. Reduced water availability, particularly during multi-year droughts, can have lasting effects on agricultural production, farm employment, local economies, and communities.

These connections also extend to ecosystems. In the Sacramento Valley, for example, working agricultural lands such as rice fields provide important habitat, and irrigation districts deliver water to wildlife refuges and other managed habitat areas. Groundwater-dependent ecosystems, including wetlands and streamside forests, support regional biodiversity and native fish and wildlife. Declining groundwater levels can threaten these ecosystems and the functions they provide. Changes in agricultural water use and groundwater management therefore have environmental as well as economic consequences. Protecting groundwater over the long term is important for agriculture, communities, and ecosystems.

Groundwater storage and agricultural demand units

The CalSim3 water systems model used in COEQWAL simulates groundwater storage conditions in 42 aquifer regions across the Central Valley (see left map below). Agricultural revenues are evaluated separately for 134 agricultural demand units within the modeled area (see right map), each representing agricultural land with specific water demand characteristics.



The colors of the polygons indicate conditions under current operations and represent whether outcomes are optimal, acceptable, at-risk, or critical (red). See **[Data and Documentation](https://coeqwal.org/data)** (https://coeqwal.org/data) for more information on how these performance levels are defined.

WHAT TO KEEP IN MIND

- Across the Central Valley, farms often rely on a combination of surface water and groundwater. When surface water is limited, groundwater can sometimes be used to fill this gap. When groundwater is also constrained, however, additional surface water may not be available to make up the difference, leading to agricultural water shortages.

- Agricultural revenues change year-to-year in response to water availability and the crops planted. Annual crops generally yield lower revenues than perennial crops but offer more flexibility to adjust planting from year to year. Higher-value perennial crops (such as nuts and fruit trees) require water every year and long-term investment, making them difficult to adjust in response to short-term shortages.

- Groundwater systems change slowly. Reversing long-term trends in declining groundwater levels may require concerted management over many years or decades. Severe groundwater depletion and land subsidence can also make recovery more difficult.

- Farmers can adapt to reductions in groundwater access by shifting crops, changing water management practices, or retiring farmland, but many of these decisions require long-term planning.

- Impacts vary by region. The Sacramento Valley and San Joaquin Valley face different groundwater conditions and constraints, so system-wide averages can mask important local impacts.

- The models used by COEQWAL primarily focus on the Sacramento and San Joaquin River basins. The Tulare Basin and other parts of the southern San Joaquin Valley are only partially represented, and changes in groundwater storage and agricultural revenues are not evaluated in these regions.
- COEQWAL explores the broader effects of limiting groundwater pumping. Because SGMA is implemented through individual basin plans that use different strategies to achieve groundwater sustainability, these scenarios do not represent how SGMA will be implemented or predict future conditions in individual basins.. For more details about SGMA, visit the California Department of Water Resources.
- Some important management options and system connections are not evaluated here. These include managed aquifer recharge and environmental benefits associated with working agricultural lands, such as habitat provided by flooded rice fields and water delivered throughout agricultural infrastructure to wildlife refuges.

WHAT MANAGEMENT STRATEGIES ARE EXPLORED

This water issue compares water management strategies that reduce groundwater use through direct pumping limits and/or reductions in irrigated crop acreage, including:

- Groundwater pumping limits in the San Joaquin Valley
- Groundwater pumping limits via reduced crop acreage in the San Joaquin Valley
- Groundwater pumping limits in the Sacramento and San Joaquin Valley

- Groundwater pumping limits via reduced crop acreage in the Sacramento and San Joaquin Valley

Together, these examine how the geographic extent of groundwater management (San Joaquin Valley versus both Sacramento and San Joaquin Valley) and different strategies to reduce groundwater use (direct pumping restrictions versus reduced crop acreage) influence water system performance under current and future climates.

For more information about each of these scenarios, visit **Data and Documentation** (https://coeqwal.org/data).

WHAT THE MODELS SHOW

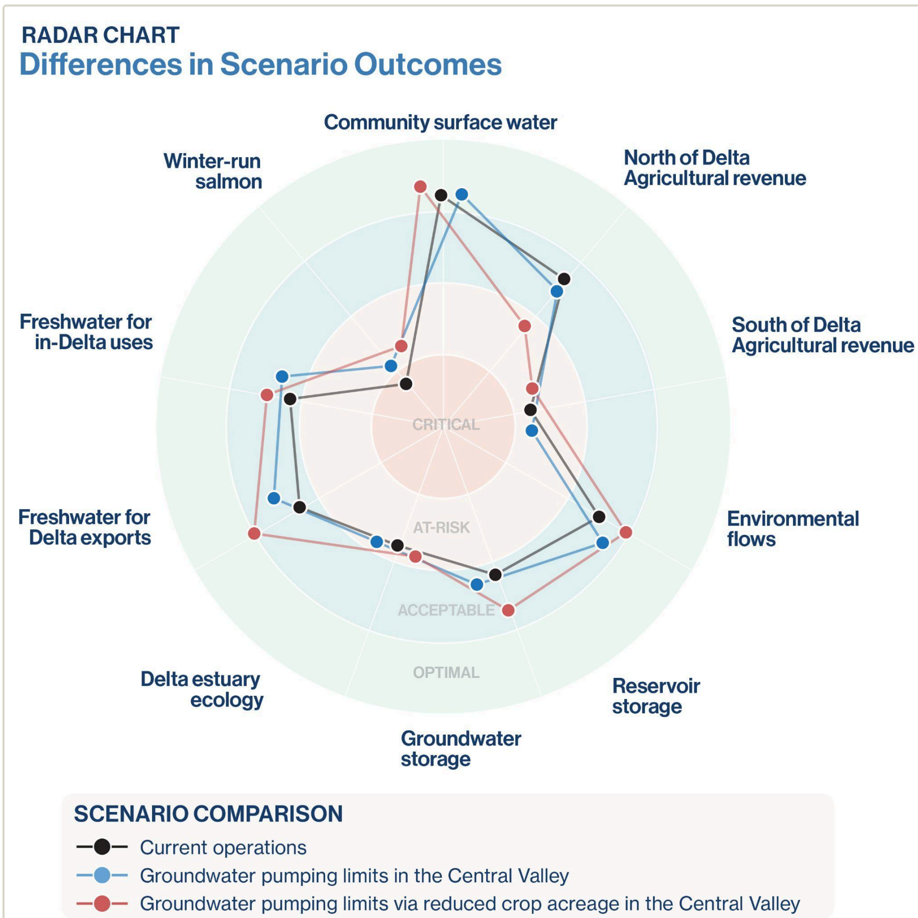
The **Explore Tool** (https://coeqwal.org/explore) allows you to explore how scenario outcomes compare under alternative management strategies and climate conditions. There are complementary ways to visualize tradeoffs, equity, and resilience of water management strategies. The examples below illustrate results from select scenarios for this water issue.

Trade-offs

How do different management strategies affect system performance across multiple outcomes?

The radar chart in the **Explore Tool** (https://coeqwal.org/explore) summarizes performance across nine key outcomes, revealing broad system-level trade-offs within and between scenarios. The chart displays the average performance across all locations of interest for each scenario, providing a system-wide view of how these management strategies influence multiple outcomes simultaneously.

This chart specifically compares **Current operations** (black), **Groundwater pumping limits in the Central Valley** (blue), and **Groundwater pumping limits via reduced crop acreage in the Central Valley** (red) under the historical hydroclimate. Agricultural revenues are distinguished for water districts north-of-Delta (Sacramento Valley) and south-of-Delta (San Joaquin Valley). The points show the average condition across all locations of interest for each outcome, classified into four outcome levels: optimal, acceptable, at-risk, and critical. See [Data and Documentation](https://coeqwal.org/data) (https://coeqwal.org/data) for more information on how these categories are defined.



The results show slight improvements in the average groundwater storage performance levels for **Groundwater pumping limits in the Central Valley,** which corresponds to a decrease in agricultural revenue. A larger improvement in groundwater storage occurs when groundwater use is limited through reductions in crop acreage. These groundwater benefits, however, come with larger reductions in agricultural revenues, particularly in the Sacramento Valley (North of Delta), where conditions fall from “acceptable” to “at risk”.

Reservoir storage improves under both groundwater management strategies, showing that changes in groundwater use can have effects elsewhere in the interconnected water system. Winter-run salmon also show modest improvements relative to current operations. Community water deliveries and Delta estuary conditions change relatively little on average. Water exports from the Delta substantially increase under the reduced crop acreage scenario. This may reflect lower agricultural water demands in the Sacramento Valley and changes in Sacramento River inflows associated with groundwater contributions. The increase in exports may also help buffer impacts to agricultural revenues in the San Joaquin Valley (South of Delta).

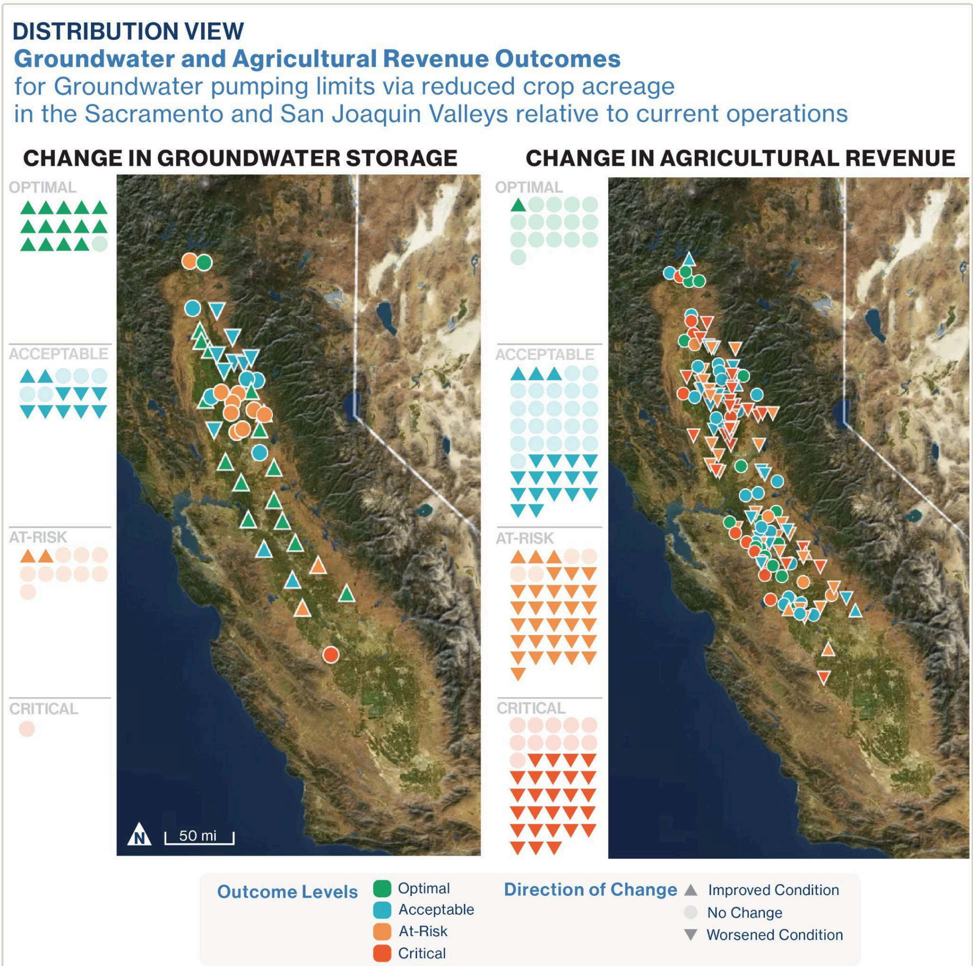
These results illustrate a central trade-off in groundwater management. Direct pumping limits produce relatively modest improvements in the average groundwater storage performance level across locations, but also smaller impacts on agricultural revenues. Reducing crop acreage produces larger groundwater benefits, but also larger economic impacts, particularly in the Sacramento Valley. This illustrates how groundwater outcomes depend not only on pumping constraints, but also on how agricultural systems adapt to reduced water availability.

Equity

Where do benefits and impacts occur, and who is most affected?

System-wide averages can hide important differences in scenario impacts. Water availability, groundwater conditions, agricultural systems, and management constraints vary considerably among agricultural water users across the areas represented in the analysis, meaning that the same management strategy can produce different outcomes in different places.

The Distribution view in the **Explore Tool** (https://coeqwal.org/explore) shows results for individual locations of interest. This figure compares outcomes for aquifer zones and agricultural districts for **Groundwater pumping limits via reduced** crop acreage in the Central Valley** relative to the **Current operations** scenario under the historical hydroclimate. Arrows indicate the direction of change relative to current operations and color represents optimal, acceptable, at-risk, or critical outcomes for the scenario. Circles on the map indicate locations where the outcome level did not change relative to current operations.



Agricultural revenue declines at most locations in the scenario with reduced crop acreage, with many falling into at-risk or critical conditions. In contrast, groundwater storage improves across most zones, with numerous locations moving into optimal condition and none remaining critical. The map indicates improvements in groundwater storage across much of the Sacramento and San

Joaquin Valleys. Agricultural impacts are more uneven, with some of the largest declines in agricultural revenues occurring in the central and southern Sacramento Valley.

Comparing the two maps makes an important distributional trade-off visible: groundwater storage improves across much of the represented Central Valley, while agricultural revenues decline at many locations. The geographic patterns do not align perfectly because groundwater storage and agricultural revenues are evaluated using different spatial units, and the magnitude of benefits and impacts varies across regions.

Overall, the Distribution view reveals regional patterns hidden by the system-wide averages and helps identify where management strategies create benefits, where they create burdens, and how evenly those effects are distributed.

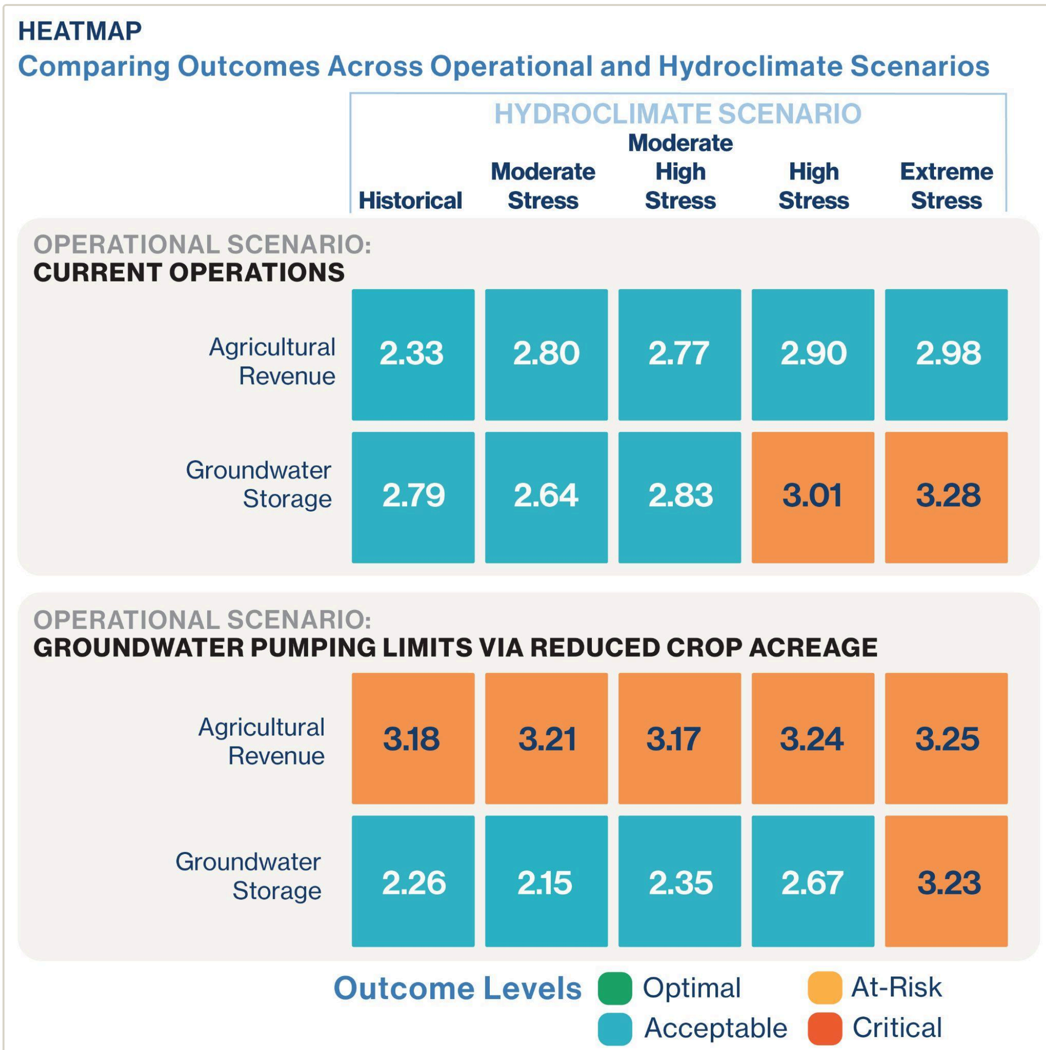
Resilience

How consistently do management strategies perform under different climate futures?

Climate change is expected to place increasing stress on California's water system. A management strategy that performs well today may respond differently as droughts become more frequent, temperatures rise, and water availability changes. The Resilience heatmap in the **Explore Tool** (https://coeqwal.org/explore) examines how management strategies perform across a range of plausible hydroclimate futures, representing increasing levels of stress to the water system. Visit **Data and Documentation** (https://coeqwal.org/data) for more information about hydroclimate futures.

This Resilience heatmap summarizes changes in groundwater storage and agricultural revenues under Historical conditions and under Moderate, Moderate-High, High and Extreme climate stress for **Current Operations** and for **Groundwater pumping limits via reduced crop acreage in the Central Valley**.

Outcomes are categorized as optimal (1.00 - 1.99), acceptable (2.00 - 2.99), at-risk (3.00 - 3.99), or critical (4.00 - 4.99), with higher numerical values indicating worse performance.



Groundwater pumping limits via reduced crop acreage in the Central Valley lowers agricultural revenues relative to **Current operations** under the historical climate and under future climates. However, agricultural revenues for Current operations respond more strongly to climate stress than for the scenario in which groundwater limits are imposed. This suggests a unique tradeoff between the two scenarios, in which the impacts of lower overall agricultural revenues are paired with a benefit of greater resilience to climate stress.

Groundwater storage shows a different pattern. Reducing crop acreage improves groundwater conditions under the historical hydroclimate, and much of this benefit persists under Moderate through High climate stress. Under Extreme stress, however, groundwater conditions deteriorate and much of the advantage over current operations is lost.

These results suggest that reducing agricultural water demand can improve groundwater resilience across a wide range of climate conditions, but increasingly severe climate stress can erode those benefits. They also show that protecting groundwater does not eliminate the broader challenge of maintaining agricultural production as water becomes more limited.

HOW TO EXPLORE FURTHER

Together, these trade-offs, equity, and resilience views make system-wide trade-offs, regional differences, and responses to changing climate conditions visible, providing a common foundation for comparison, discussion, and learning. Visit the **Explore Tool** (https://coeqwal.org/explore) to learn more about how different groundwater management strategies affect agricultural production, groundwater storage, and other outcomes across regions and climate conditions.

If this is the first time using the **Explore Tool** (https://coeqwal.org/explore), we recommend visiting the **Get Started** (https://coeqwal.org/learn) section of the site before you begin your exploration.

CONTACT US

Do you have questions or feedback about this water issue and the COEQWAL project? Please email coeqwal@berkeley.edu (mailto:coeqwal@berkeley.edu)