

Climate Change and Rural Water for Frontline Communities in the Southwest United States

Climate change is threatening rural water supply and quality in the Southwest United States and will intensify water challenges in the coming years.¹ Climate impacts such as prolonged drought conditions and extreme high temperatures paired with groundwater depletion and reduced mountain snowpack are increasing the risk of water supply shortages in the region.^{1,2} Climate change models project an increase in temperature and an overall decline in average annual precipitation in the Southwest, though punctuated with extreme precipitation and more damaging flooding events.¹

As such, rural communities in the Southwest face heightened risks to their water systems. Small, rural community water systems can also be less resilient to climate impacts due to a lack of resources such as funding or staffing. In the Southwest, large populations of Hispanic, Latino, and Indigenous communities disproportionately experience climate impacts due to historic and current inequalities including discrimination and lack of political representation.^{3,4} While many frontline communities have demonstrated adaptive solutions to build resilience, more innovative strategies and approaches are needed to face the challenges that will come with a changing climate.

The Southwest United States, which here we define as the US National Climate Assessment's 6-state region of Arizona, California, Colorado, New Mexico, Nevada, and Utah, totals one-fifth of the country's land area (Figure 1).⁵ Here we review observed and projected impacts of climate change in the Southwest with a focus on impacts to rural water supply and quality in frontline communities—those experiencing disproportionate impacts to their water systems first and worst. We begin with a summary of climate impacts and how they are projected to impact water access and quality in the region. This is followed by a discussion of impacts to rural water supply, frontline communities in the region, and climate adaptation actions they have taken. Finally, we discuss how our collaborative and community-centered research aims to highlight strategies and approaches for building equitable, climate-resilient rural water systems.



Figure 1: Map of Southwest Region

Source: US Climate Resilience Toolkit and UNC Asheville National Modeling and Analysis Center.⁶

Key Takeaways

1. As the climate changes in the Southwestern United States, drought, extreme heat, flooding, and wildfires are expected to increase throughout the region and will jeopardize rural water access and quality.
2. Rural frontline communities across the Southwest including Hispanic, Latino, and Indigenous populations face increased risk of climate change threats to their water systems.
3. Climate change preparedness and response actions are already underway in the region, such as water efficiency solutions and improved water governance, which are essential in addressing the Southwest's rural water problems in the face of future climate change.

Observed and Future Climate Change Impacts on Rural Water in the Southwest

Climate change observations indicate that the already water-stressed lands in the Southwest United States are becoming increasingly drier as warmer temperatures increase evaporation and reduce soil moisture.¹ The Southwest will also experience more precipitation variability including extreme precipitation events that cause disruptive flooding.^{1,7} Since ~2000, the Southwest experienced a “megadrought” that were the driest ~24 years in 1,200 years (Figure 2).^{1,8} Many climate models indicate that human-induced warming will continue to increase

precipitation variability from daily and monthly to interannual and decadal timescales, leading to increases in periods of both extreme precipitation and drought.^{1,7} Climate change has increased evaporative demand and, paired with higher temperatures and increased drought, has reduced water flows in major river basins like the Colorado River and Rio Grande.¹ These reduced water flows coupled with growing water demands have led to many of the region’s lakes and reservoirs reaching historically low levels.¹

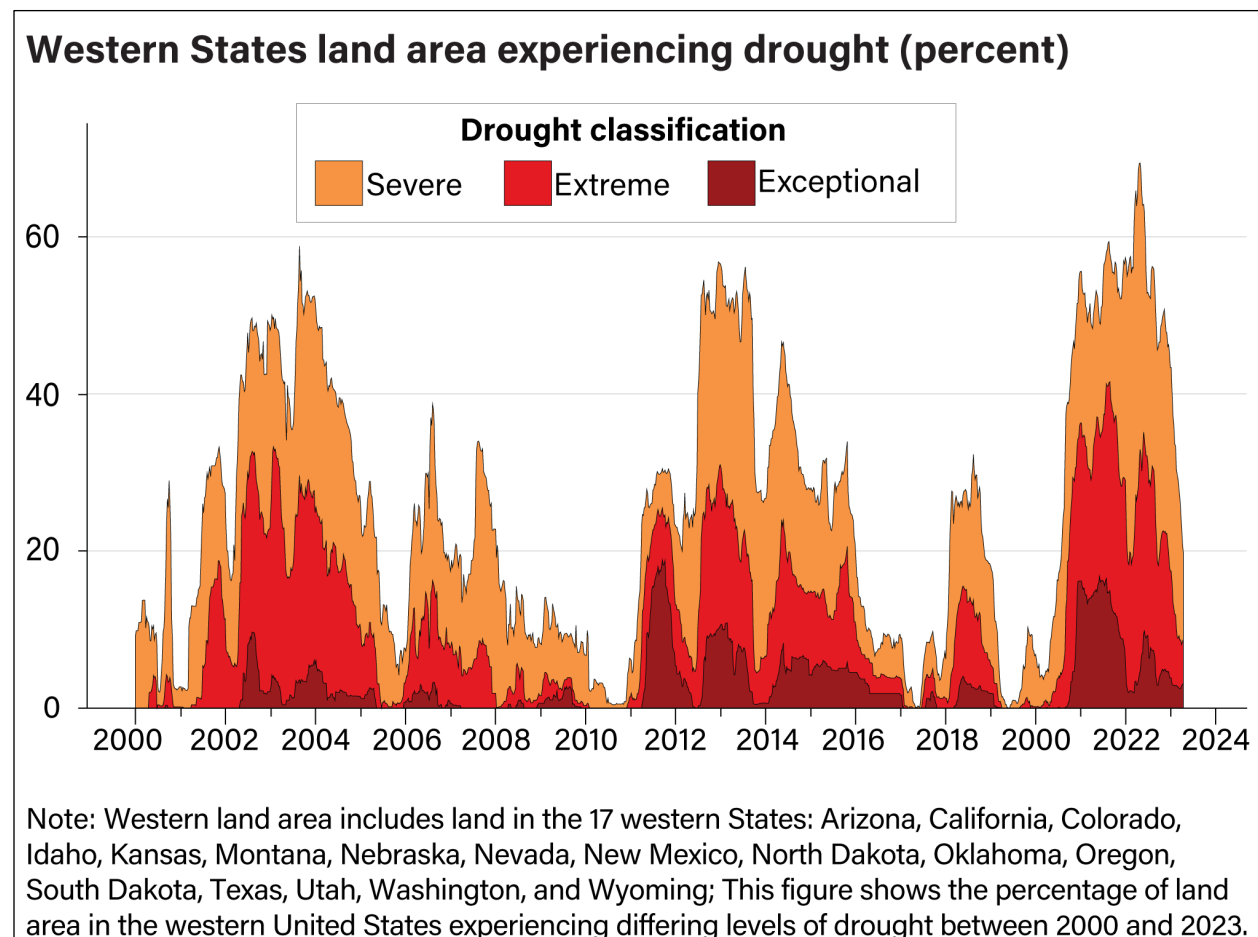


Figure 2: Percent of Land Area in Western States Experiencing Drought 2000–2023
 Source: USDA Economic Research Service 2023⁹ using data from the US Drought Monitor.

Average temperatures have increased across the Southwest compared to long-term averages (Figure 3), and more frequent extreme heat events in the Southwest are projected under continued climate change.¹ Overall warming trends and extreme heat events affect water quality and supply in several ways. Extreme heat can contribute to algal blooms in surface waters, endangering sources for drinking and water for recreation.^{10,11} Drought combined with extreme heat causes “hot drought” where higher temperatures amplify droughts and result in decreased water availability thereby increasing water shortage challenges.^{12,13} Extreme heat also increases water use and demand as people tend to use more water to keep cool, remain hydrated, and irrigate landscapes, putting additional pressure on water resources.¹⁴

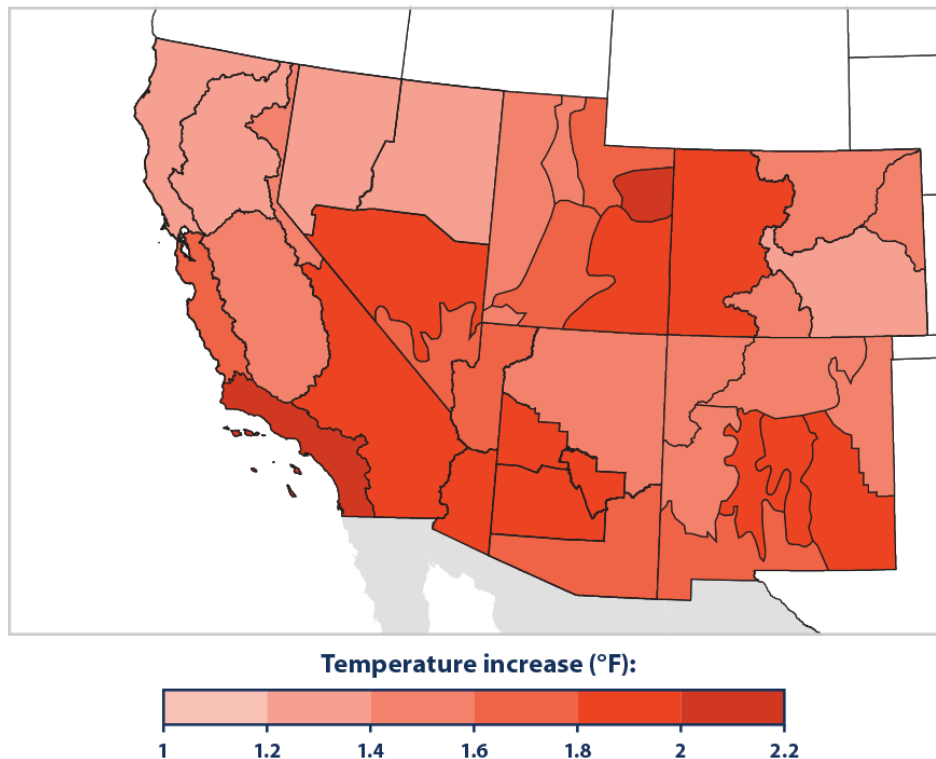


Figure 3: Average Temperature Differences in the Southwest, 2000–2020 Versus the Long-Term Average (1895–2020)

Source: US Environmental Protection Agency and National Oceanic and Atmospheric Administration 2021.¹⁵

Warmer and drier conditions also lead to increased wildfire risk. In the Southwest, climate change has caused wildfires to increase in size, severity, and frequency in many areas, and this is expected to continue to put rural water resources at risk.¹ Seven of the 10 largest wildfires in the United States from 2020–2021 occurred in the Southwest.¹ On the household scale, wildfires can melt and rupture water meters and water pipes.¹³ On a larger community scale, wildfires can damage water intake systems or water treatment systems.¹⁶ Beyond infrastructure damage, wildfires can render drinking water unsafe due to contamination of water supply with chemicals and sediment and an increase in runoff and erosion when rainfall occurs in burned areas.^{16–19}

Following a fire, landscapes face erosion and potential landslides, and downstream reservoirs can be contaminated by these sediments.^{19,20} Waterways that are located downstream of fire-impacted forested land see an increase in temperature and the concentration of solids, nutrients, and heavy metals following a fire.¹⁶ Drinking water supplies can be at risk for years following a wildfire,²¹ and while the economic research is limited to date, the costs of wildfire to water systems could be significantly increased for years to come.^{22,23} Decentralized systems such as private, domestic wells can suffer the same water quality effects after a wildfire, however, these systems can face a much slower recovery process.¹³

Regional Climate Impacts on Rural Water Supply

Water infrastructure in the arid Southwest is especially complex and largely designed to move water from areas with a surplus to areas with limited supply.⁵ This infrastructure also relies on reservoirs, canal and pump structures, groundwater pumps, hydropower, and water efficiency technologies, as well as engineering to mitigate flooding and other risks.² Much of this infrastructure was designed to use snowmelt as a primary water source, and it was historically assumed that this snowmelt would always be present and could be relied upon.^{2,24} However, mountain snowpack has declined over the last century due to warming trends from climate change.¹ Of additional concern, climate change has accelerated evapotranspiration in the region, greatly reducing runoff that feeds the watershed, even in years of near-normal snowpack.²⁵ Climate models project the western United States could experience persistent low-to-no snow conditions in approximately 35–60 years.²

The Colorado River Basin is a major source of water in the Southwest, and while estimates vary, it serves somewhere between 35–40 million people.^{26–28} The Lake Mead and Lake Powell reservoirs are at historically low levels and cannot provide sustainable water supply in the Southwest unless consumption is reduced to match declining water supply levels.²⁹ In 2021, the US Bureau of Reclamation declared the first water shortage on the Colorado River after over 22 years of historic drought, climate change, and a growing difference between water supply and demand.¹ Water levels in Lake Mead fell to 27% capacity in 2022 compared to 98% capacity in 2000.¹ The Colorado River is fed by snow runoff in the Rocky Mountains, and snowpack has been declining in recent years.² The Colorado River Basin is in one of the most productive agricultural regions in the world, so competition between drinking water and irrigated agriculture, among other uses, also creates water shortage challenges.³⁰ Within the Colorado River Basin, an estimated 70% of water consumption is for the agricultural sector.³¹ Increasing drought severity in the Western United States raises overall water demand for irrigation and, in turn, accelerates groundwater depletion.³²

As climate change intensifies drought or changes the timing, amount, and location of precipitation, recharge of groundwater can be even further reduced, diminishing the physical accessibility of water resources.^{33,34} Groundwater depletion is a major concern for frontline communities dependent on shallow wells that might not be able to afford alternative water sources.^{11,13,35} Declining groundwater resources may also lead to higher costs for community water system users in the Southwest.¹³ Small and rural water utilities dependent on groundwater are particularly vulnerable, and during droughts these utilities might need to purchase a more expensive water supply, add treatment steps to degraded water quality, or pump groundwater from deeper in an aquifer.³³ Thus, rural water costs may increase in response, creating more burden for low-income households.³⁷

Frontline Communities in the Rural Southwest

The Southwest is home to numerous rural frontline communities with a great diversity of cultures, economies, and landscapes.^{5,38} Frontline communities are those that are overburdened and under-resourced who face disproportionate “first and worst” impacts of climate change on their water and sanitation systems or access to water. The region includes large low-income Hispanic or Latino and Indigenous populations who have endured a long history of discrimination, political marginalization, and a lack of sufficient infrastructure.³⁸ The region also has some of the highest poverty levels in the country, underpinning the climate vulnerability of rural water systems in communities already affected by water quality, access, and affordability issues.^{13,38,39} Nevada, Arizona, and New Mexico have particularly high levels of poverty. In 2021, 18.6% of New Mexico’s population was living in poverty.⁴⁰ Poverty rates for minority populations

in New Mexico were considerably higher with 30.6%, 24.8%, and 20.3% of the state’s Native American and Alaska Native, Black, and Hispanic populations, respectively, living in poverty.⁴⁰

A number of water insecurity hotspots, which are places with a high concentration of households lacking water and sanitation access, are found in the Southwest region.³⁹ Many of these communities are those experiencing high levels of poverty and are increasingly affected by a changing climate, including severe impacts on water systems or water access through worsening incidences of temperature and precipitation extremes, flooding, wildfire, and prolonged drought.^{4,13} White et al. (2023) found that during and after climate disasters, Southwest region communities with high socioeconomic risks are expected to be less resilient because of factors that included low income to poverty ratio, communication barriers, households without full time employment, disability, lack of health insurance, lack of internet access, and residents over the age of 65 (Figure 4).

Community Resilience Estimates for the Southwest

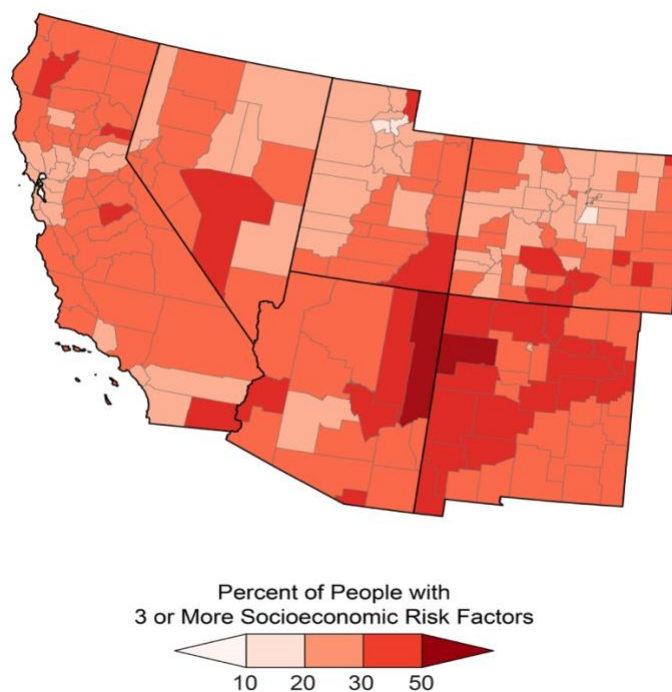


Figure 4: Community Resilience Estimates Across the Southwest Based on Socioeconomic Risk Factors

Source: White et al. 2023.¹ This analysis used household characteristics from the American Community Survey and the Population Estimates Program to estimate county-level community resilience across the Southwest. Darker shading indicates a higher proportion of the population has less capacity to recover from a disaster.

Drought impacts also disproportionately affect low-income communities and communities of color.¹³ A study by the Pacific Institute found that in California people of color, low-income households, and communities already burdened by pollution suffered the most severe drought impacts.³⁶ Indigenous communities can also experience more intense drought impacts as they are often located in rural areas with distant water infrastructure or a lack of critical water infrastructure, which for some requires hauling water to their homes.^{39,41} Small and rural

frontline communities are often among the most vulnerable to drought but might lack the resources or plans to cope with the impacts.³⁶

Drought can also disproportionately impact rural frontline communities through a rise in the cost of water.³⁶ The cost of energy and water bills is expected to increase in the Southwest as climate change intensifies, and low-income households will experience more difficulty paying for these essential services.³⁸ In times of water scarcity, water costs may increase because a water utility must find an alternative supply or pump groundwater from deeper in an aquifer.^{36,37}

Small, rural drinking water systems are particularly challenged in providing affordable, safe, reliable drinking water and wastewater services that meet both federal and state regulations.⁴² Rural community water systems are more likely to face contamination compared to urban systems, and often lack the financial, technical, and managerial capacity to address chronic drinking water challenges.^{43,44} All of these issues combine to make small water systems particularly at risk to climate change impacts, especially when they rely on a single drinking water source.⁴⁴

Hispanic and Latino Populations

Many states in the Southwest have large numbers of Hispanic or Latino populations. Hispanic and Latino people make up 40.2% of the population of California, 32.3% of Arizona, and 50.1% of New Mexico.⁴⁵ Over 60% of the Hispanic population in the Southwest is Mexican American.⁴⁶ In 2021, 42% of Central American immigrants to the United States lived in the Southwest region and many of them are low-income, children, women, or Indigenous.^{1,47}

Hispanic and low-income communities often receive low-quality drinking water, have inadequate sanitation services, and have historically been left out of water management processes and decisions.^{1,13} Hispanic and Latino individuals also have high labor force participation in weather-exposed industries and face projected loss of labor hours due to extreme temperatures.^{4,13} Extreme heat is especially impactful to vulnerable groups such as outdoor laborers, the elderly, and those experiencing homelessness.¹³ Three states in the Southwest—New Mexico, Arizona, and California*—are home to colonias, which are unincorporated, low-income areas along the US-Mexico border that often lack clean water, adequate sanitation, indoor plumbing and water infrastructure, and/or electricity.^{39,48} In Arizona, there are 104 colonias with a combined population of 278,202; in New Mexico there are 154 colonias with a combined population of 157,408; and there are 35 colonias in California with a combined population of 46,2469.⁴⁸ Research has shown that colonias are highly vulnerable to contaminated water from both wet and dry extremes.⁴⁹

California's Central Valley has a high concentration of Hispanic communities and is also a water insecurity hotspot.³⁹ Even in towns with water and wastewater infrastructure, the communities they serve often have little to no input on how they are managed.³⁹ Rural Hispanic and Latino communities in the Central Valley were historically discouraged from incorporating into local jurisdictions and thus did not receive the same access to infrastructure funding, leaving a legacy of water challenges.³⁹ These communities often have poorly constructed septic systems and sewers, and many lower-income communities rely on private wells for drinking water.⁵⁰ These wells are typically shallow with small pumping capacity and more likely to fail during drought.⁵¹

* Texas is also home to many colonias but is not in the Southwest region, so not included here.

As climate change increases drought and changes the intensity or timing of precipitation events, groundwater recharge will be reduced.^{10,13} Historically, most California water supply came from surface water, although use of groundwater has increased due to the declining availability of surface water.³⁴ The depletion of groundwater resources impacts water supply systems and communities that rely on them.^{13,52} The approximately 1.5 million Californians reliant on domestic wells for water supply—one-third of which are in the Central Valley—face reduced recharge.⁵¹ This reduced recharge results in a decline of water access and disproportionately affects those communities.¹³

Indigenous Populations

The Southwest region has the largest Indigenous population in the United States, which includes 1.5 million Native Americans, 182 federally recognized Tribes, and numerous other non-federally recognized Tribes.⁵ According to the US Census Bureau, those identifying as American Indian or Alaska Native comprised 11.2% of the population in New Mexico, 5.2% of the population in Arizona, 1.7% of the population in Colorado, Nevada, and California, and 1.5% of the population in Utah in 2022.⁵³ Indigenous communities are on the frontline of experiencing the brunt of climate change impacts on water systems and uses.⁴¹ For centuries, Indigenous peoples of the Southwest were relegated to lands with limited water and poorly functioning water and sanitation systems, and they have struggled to gain federal recognition of their water rights.⁵ For example, 12 of the 30 federally recognized Tribes in the Colorado River Basin still have unresolved water rights claims.⁵⁴

Native American households are 19 times more likely when compared to White households to lack indoor plumbing with running water.⁵⁵ One example of this disparity is the Navajo Nation, where approximately 30% of households do not have running water or indoor plumbing and rely on hauling drinking water from distant sources.^{13,39,56} The Southwest is also home to many abandoned mines disproportionately located within tribal watersheds, leading to contamination of tribal lands and continued drainage of contaminated mine water.⁵⁷ Despite these challenges, Indigenous peoples and other frontline communities have been at the forefront of creating and implementing climate actions.

Climate Actions

Many Indigenous communities have demonstrated proactive adaptations to climate change; however intergenerational trauma, settler colonialism, extractive infrastructure, and socioeconomic and political pressures have constrained some adaptations to current and future climate change.^{58–60} Despite these challenges and barriers, Indigenous peoples in the Southwest have been leaders in innovative climate actions grounded in Indigenous knowledges and practices, cultural models focused on relationships, and partnerships with universities and other research institutions.^{3,5,41,58} Tribes are often at the forefront of implementing locally and scientifically based actions to prepare for and respond to climate change and creating systemic shifts to reconnect people with the environment.⁴¹ The Institute for Tribal Environmental Professionals created trainings on climate adaptation planning that have reached over 420 Tribes and Tribal organizations.³ Many Tribal climate change responses have blended different values and ways of knowing and observing from Indigenous knowledges and Western sciences, including food security initiatives, restoration efforts, and climate emergency response systems.³ Youth-led Indigenous movements are also at the forefront of climate action and adaptation.^{3,61}

Future climate change projections for shifting precipitation patterns, declining snowpack, earlier snowmelt, and more extreme droughts, wildfires, and catastrophic flooding necessitate climate action planning and implementation throughout the Southwest region (Figure 5). As such, rural decision-makers, including community leaders, local governments, and water managers will need the resources and flexibility required to satisfy water demands throughout the year, especially during times of high demand.⁶² Climate changes will lead to further disruption to local cultures, well-being, and livelihoods in the Southwest. In response, frontline communities are actively engaged in efforts to respond to climate change impacts and vulnerabilities. This includes things such as climate-resilient water policy and governance measures, improving and/or installing climate-resilient water infrastructure, water efficiency and reuse, nature-based solutions, soil restoration, reductions in the amount of water needed for crops, and mitigation of fuel sources for wildfires, among others.^{1,5}

Climate Change Indicators, Impacts, and Responses in the Southwest

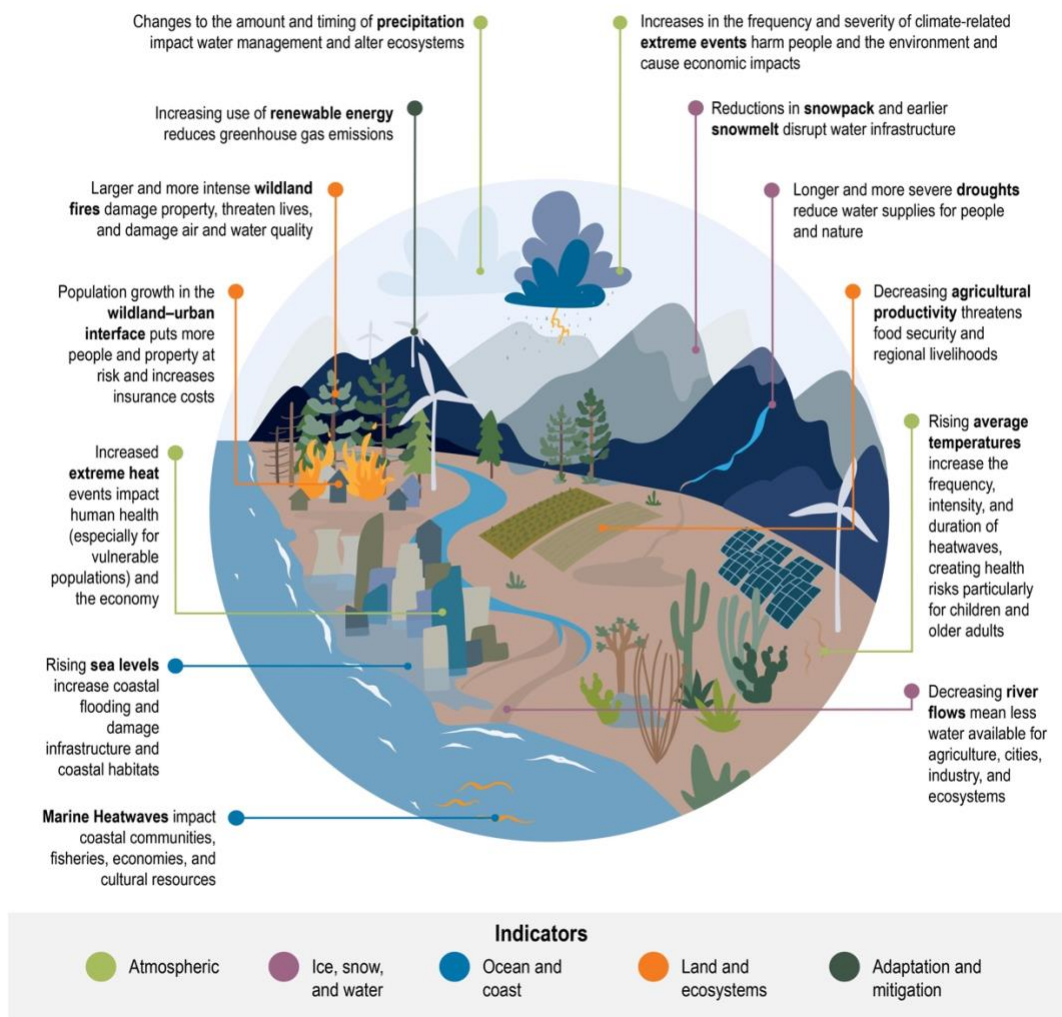


Figure 5: Climate Change Indicators, Impacts, and Responses in the Southwest

Source: White et al. 2023.¹

Throughout the Southwest, communities are already implementing adaptive water governance and management strategies.¹ For example, various drought response measures have been taken in the Colorado River Basin, involving diverse participants to reach solutions.^{1,63,64} There are options to address projected water risks, many of which are already happening to some extent, such as water efficiency improvements, refined groundwater management, investment in water banks, development of recycled wastewater and other alternative supplies, and water transfers (the right to use water in exchange for some form of compensation).³⁰ However, a lot of work remains to prepare rural water systems, especially those serving frontline communities in the Southwest, for what climate change will inevitably bring.

Partnering to Understand and Leverage Frontline Communities' Resources for Resilience

Partnerships between technical experts, water managers, and communities that co-produce actionable knowledge and decision-support information and tools can help advance equitable, climate-resilient rural water systems despite uncertainties about future conditions.² A partnership between the Pacific Institute, Rural Community Assistance Partnership, and Livelihoods Knowledge Exchange Network is assessing the risks and climate resilience of rural water systems in frontline communities across the contiguous United States with a focus on the Central Appalachia and Southwest regions. This assessment aims to co-identify and co-design strategies and solutions for climate-resilient water systems with residents and leaders in rural frontline communities. We also aim to contribute to community capacity-building for climate and water resilience in rural areas across the United States and catalyze the production of actionable knowledge on adaptation and emergency disaster preparedness. This partnership is leveraging our organizations' expertise in co-developing collaborative, policy-relevant, multistakeholder research and knowledge exchange by providing technical assistance, training, and decision-support resources and tools to support rural communities.

Contributors

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