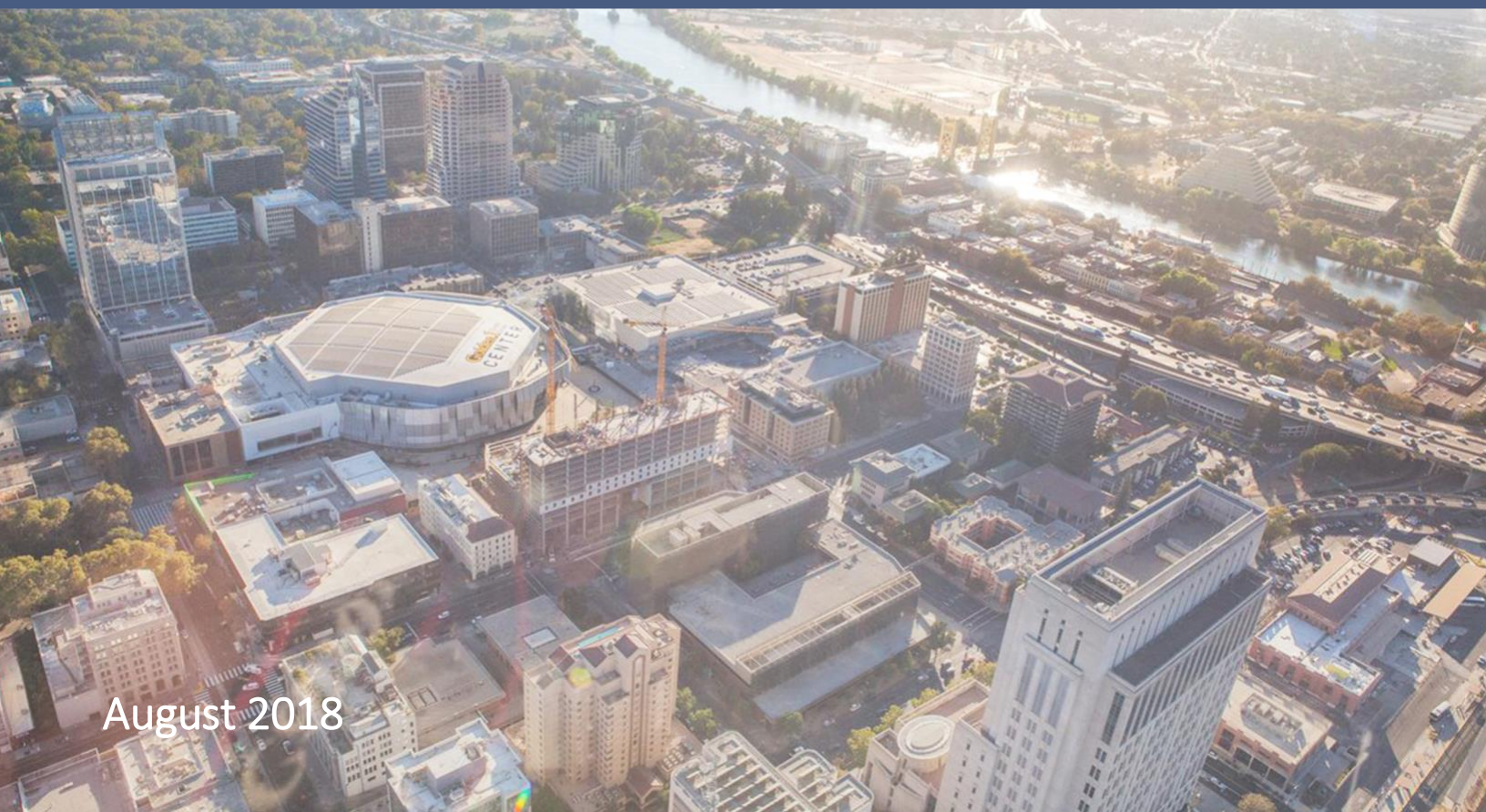
ARCCA

Alliance of Regional Collaboratives for Climate Adaptation

From Mountains to Cities

Exploring California's Urban Connections to Sierra Nevada Ecosystems



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A Message from ARCCA's Chair

Quick – think of the word "California." What comes to mind? Did you picture Half Dome in Yosemite Valley? Or did you see a grove of giant redwoods? Or was it the Golden Gate? Or Lake Tahoe? Or a wide and sunny beach?

Here's what you might not have visualized: a suburban home sporting a large green lawn, or the apartment building around the corner. In your mind's eye, you saw a beautiful place, a place worth visiting, not where most Californians live. And that's okay – but it's important to realize that California's vast number of homes and green lawns depend on its forests. This is no small feat. California has some seven million single-family homes and a couple million apartments buildings. California's cities depend on the resources provided by lands like Yosemite and Lake Tahoe and our forested mountains.

The following report by the ARCCA chronicles the dependence California cities have on its mountains and forests. The report makes clear that urban communities could profoundly benefit from treating rural resources with care.

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Introduction

The Sierra Nevada provides Californians across the state with a multitude of benefits including clean air and water, flood protection, recreational opportunities, jobs, biodiversity, and carbon sequestration. However, climate change threatens to disrupt these services with detrimental consequences for both urban and rural communities. To address the accelerating and compounding impacts of climate change and ensure the health and resilience of Sierra Nevada ecosystems through equitable and holistic solutions, urban and rural decision-makers must collaborate.

This paper is a call to downstream stakeholders to collaborate with rural communities and begin **incorporating the consideration of ecosystem benefits into their decision-making processes**.

Ongoing drought conditions throughout California provide an example of how altered climatic conditions can suppress ecosystem services. Decreasing levels of snowfall in the Sierra Nevada mountains have yielded less water for both urban and agricultural uses. Available surface water decreased by 50% in 2015 over previous years, causing farmers across the state to cut farm acreage by 6% and reducing agricultural sector revenue by $2 billion,[i] which coincided with statewide residential water restrictions. Less snowfall contributes to drier conditions, increasing tree mortality and wildfire risk, as well as increasing groundwater use and subsidence rates (the gradual caving in or sinking of an area of land).

The enormous challenges that climate change presents must be met with **unparalleled levels of collaboration across the urban-rural transect**.

Investments in proper forest and watershed management, rural development, and a cultural shift towards conservation and stewardship can restore critical ecosystem services. In addition to clean air, water, and natural resources, healthy ecosystems reduce the risk and severity of wildfires and floods, provide critical habitats and recreational opportunities, and increase carbon sequestration. Through enhanced coordination and creative solutions, these investments can also provide economic opportunities for low-income rural residents, build capacity of public agencies and organizations in rural areas, and lead to more equitable outcomes for all Californians.

This paper showcases how communities across California depend on the valuable services provided by Sierra Nevada forests and headwaters, and the risks exacerbated by climate change that endanger these critical natural lands. By recognizing the essential role of Sierra rural communities as stewards of California's natural resources – and thereby stewards of the state's economic, environmental, and social vitality – this paper explains why greater investment in and inclusion of rural regions by urban communities is critical to the livability and longevity of urban populations, as well as the state's overall climate strategy. Without the involvement of urban communities, rural regions and their ecosystems are unable to manage and invest in the current and future challenges to the vitality of the state's natural resources. However, with adequate investments in the Sierra Nevada's natural resources and rural communities, California can holistically adapt to current and future risks to water quality and supply, forest resilience, public health, and economic vitality while transforming rural engagement in statewide conversations on climate adaptation.

This introductory paper is the first of a larger series and will be followed by additional reports that identify policy opportunities, strategies to develop and deepen collaborative efforts, and on-the-ground solutions to enhance ecosystem resilience.

Sierra Nevada Ecosystem Benefits

Ecosystems, communities of living organisms (plants, animals, fungi, and microorganisms) and their associated non-living components (water, air, soil, sunlight, and temperature) interact as a system to provide a multitude of services that benefit people and support our ways of life. These ecosystem services include:

1. **Supporting services**: the underlying processes that help sustain life and include the nutrient cycling, photosynthesis, the creation of soils, and the water cycle;
2. **Provisioning services**: resources and materials that can be extracted for our benefit, including fresh drinking water, energy sources, timber, and medicinal resources;
3. **Regulating services**: the benefits obtained from the regulation of ecosystem processes such as carbon storage and climate regulation, erosion and flood control, water purification, and pollination; and
4. **Cultural services**: the nonmaterial benefits that people obtain from ecosystems, which include recreation and relaxation, spiritual enrichment, intellectual development, aesthetic values, and the role of ecosystems in local, national, and global cultures.[ii]

Each of these critical services enable the transfer of resources from the mountains of the Sierra Nevada to downstream urban communities as water, timber supplies, recreational opportunities, and other essential benefits. Without these critical ecosystem services, urban communities would have far less access to many of the basic amenities of life. Networks of natural resources such as airsheds and watersheds carry these services to beneficiaries, linking communities and regions together through their mutual dependence on the health, quality, and quantity of critical ecosystems and natural resources.

Ecosystems are dynamic and are impacted by environmental and climactic disturbance such as prolonged drought and rising temperatures but can also help buffer communities from these impacts. Intervention to protect one aspect of an ecosystem can often enhance additional ecosystem services, providing co-benefits to communities that depend on them. Protecting and enhancing ecosystems services can serve as a core strategy to adapting to climate change in order to improve community resilience, public health, carbon sequestration, air quality, alternative energy production, water quality and supply, natural water storage, recreation, tourism, and much more.

Watersheds

Watersheds, the basin-like landforms where rainfall, snowmelt, and spring runoff collect and drain to a common outlet, represent the backbone of most ecosystem services.[iii] Watersheds also include networks of underground aquifers and groundwater basins that can store and transport water in similar ways as above-ground rivers or lakes. They also serve as the state's natural circulatory system: collecting, storing, and distributing water resources throughout the state for residential, agricultural, commercial, and other beneficial uses.

The quality of watersheds directly impacts the quality and quantity of water available to downstream urban communities, as well as the functions of all other ecosystem services benefiting human life.

Many of California's primary watersheds originate in the Sierra Nevada mountains, which supply over 60% of the developed water supply used throughout the state each year. Some of California's largest cities and counties rely on Sierra Nevada watersheds for their water supply:

- The **San Francisco Bay Area** receives as much as 85-90% of their water from the Sierra Nevada. Sierra mountains provide natural water storage via snowpack and Sierra forests and meadows ensure water quality and reliability as snowmelt flows over 100 miles through the Tuolumne and Mokelumne rivers to supply water to these areas.[ivv]
- Half of the **Los Angeles Basin's** water supply flows from the Sierra mountains through the Feather River to Lake Oroville, where it is stored before entering the State Water Project. The State Water Project transports water from Lake Oroville to Southern California, providing approximately 50% of the municipal water used by the people of Los Angeles.[vi] An additional third of the Los Angeles water supply is provided by the Owens River on the east side of the Sierra Nevada via the Los Angeles Aqueduct[vii].
- Water from the Sierra Nevada region feeds up to half of the freshwater inflow to the **Sacramento-San Joaquin Delta**, providing water for three million acres of agricultural land and the 25 million people living in California's Central Valley.[viii]

In many ways, downstream communities benefit the most from the ability of watersheds to store water and control its flow. When healthy and properly functioning, watersheds ensure a reliable supply of water year-round while decreasing the likelihood of downstream flooding. Snowpack in particular serves as a crucial component to this process, serving as a naturally-occurring reservoir to store water during winter and slowly melting to feed into streams and rivers, as well as to infiltrate into the ground.[ix] This replenishes and recharges groundwater supplies that sustain California's forests and meadows throughout the year and provides groundwater either as a direct water source or a source to augment surface water streams and rivers during drier months.

Montane Meadows

The Sierra Nevada meadows play a vital role in controlling floods, capturing carbon, reducing erosion, and regulating water storage, quality, and temperature, as well as providing iconic aesthetic and recreational value to the Sierra region. However, according to the Sierra Meadows Strategy report, approximately 40-60% of meadows have been degraded or are not fully functioning[x]. The source of meadow degradation can be traced back to multiple stressors including overgrazing, road construction, the state's altered fire regime, invasive species, development, recreational use, and climate change.

Figure 1: Meadows, like this one in Tulare County, provide water storage and ease water management for downstream communities in Los Angeles and the Central Valley.

Although the 17,000 montane meadows in the Sierra Nevada only comprise 2% of the region, the diversity found in these ecosystems provide important habitat for over half of the species located in the Sierra Nevada and are dependent on the abundance of water during drier seasons. To represent the critical importance of montane meadows to the health of California's natural resources, The Sierra Meadows Partnership was formed from multiple state and federal agencies and nongovernmental organizations with the goal to increase the pace, scale and efficacy of meadow restoration in the Sierra region[xi]. Sierra Nevada meadows are critical to the State's natural resources due to their ability as natural reservoirs to absorb and regulate seasonal water flow and snowmelt.

> Healthy meadows are highly resilient and act as buffers for large fluctuations in sediment and water flow from upstream regions, essentially providing protection from climate variabilities, such as flooding experienced by downstream communities.

The Sierra Nevada Meadow Restoration Business Plan compared the Sacramento Valley Sites Reservoir to the average meadows restoration in 2010. As a solution to California's water future, the report it highlights meadow restoration as a cost-effective approach, estimating the ability to save $238-$435 per acre-foot of potential increased water storage over a 10-year period[xii].

A Brief History of California's Water Management Practices

California's modern water management system began to take shape in the mid-nineteenth century as the discovery of gold and the subsequent Gold Rush brought in a flood of settlers. During this period, California experienced its first effort to industrialize water resources. In order to channel water to the gold mines, miners created a network of canals and ditches that altered the Sierra Nevada landscape and changed the way water resources would be regarded and used for years to come.

Miners used the principle of "first in sight, first in right" to establish their right to water, laying the foundation for today's appropriation rights system[xiii] that has been in place since 1951,[xiv] granting rights to allow the diversion of water to lands without direct access to water. A year later, landowners along California rivers and streams were granted riparian rights, giving landowners the right to use water adjacent to or flowing through their property by virtue of land ownership.

By the early twentieth century, rapid population growth and expansion of agriculture impacted water policy and management in the state. As disputes between owners of riparian and appropriation rights increased, a comprehensive system was needed to regulate water management. In 1914, the state legislature established the Water Commission to monitor permits for water rights.[xv] Over time, the Water Commission became known as the State Water Resource Control Board (SWRCB) and evolved to not only manage water rights and usage, but also watersheds, which includes protecting water quality, fish and wildlife, and recreational uses.

Since the State Water Project (SWP) was built in 1966, the Sierra Nevada watershed has served as the primary hydraulic link between northern and southern California. The SWP is a 3.5-million-acre reservoir along the Feather River in Oroville, which delivers water to two-thirds of California's population.[xvi] The project captures and diverts water from the Sierra Nevada to communities in the Sacramento Valley, San Francisco Bay Area, and San Joaquin Valley, before traveling through the California Aqueduct and over the Tehachapi Mountains to the Metropolitan Water District of Southern California. Roughly 30 percent[xvii] of Metropolitan Water District of Southern California's water supply is provided by the SWP.

Most of the state's water management system is highly decentralized with numerous agencies at state, regional, and local levels. Each local and regional agency oversees local flood management, wastewater

treatment, and drainage management, or is responsible for delivering water to urban and rural communities[xviii], while the SWRCB and the California Department of Water Resources manage the state's water supply and quality including projects such as the SWP.[xix] Decentralization enables flexibility and swift responses to local challenges; however, insufficient coordination has contributed to groundwater overdrafts of aquifers and degraded ecosystems. Fragmented water management, combined with climate change and decreased funding from federal and state agencies, poses significant threats to the Sierra Nevada ecosystem, which are likely to magnify over the next century as climate change accelerates.

A more recent development in California's water management is Integrated Regional Water Management (IRWM), which began in 2002 when the legislature passed the Regional Water Management Planning Act (SB-1672). An IRWM is an effort to identify and implement water management solutions on a regional scale that increase regional self-reliance, reduce conflict, and manage water to concurrently achieve social, environmental, and economic objectives. This collaborative approach delivers higher value for investments by considering all interests, providing multiple benefits, and working across jurisdictional boundaries. Examples of multiple benefits include improved water quality, better flood management, restored and enhanced ecosystems, and more reliable surface and groundwater supplies.

Forests

Healthy forests are an integral component of the Sierra Nevada watershed, providing a multitude of benefits to both urban and rural communities. Forests filter and regulate the flow of water, sequester and store carbon from the atmosphere, provide habitats for hundreds of species, provide recreational opportunities, and are a major source of wood products, hydro-electric power, and biomass energy. The Sierra Nevada headwater forests provide up to two-thirds of California's water, half of the state's annual timber yield, and 15% of the state's energy demand with additional capacity to provide more renewable energy through biomass, solar, and wind power.

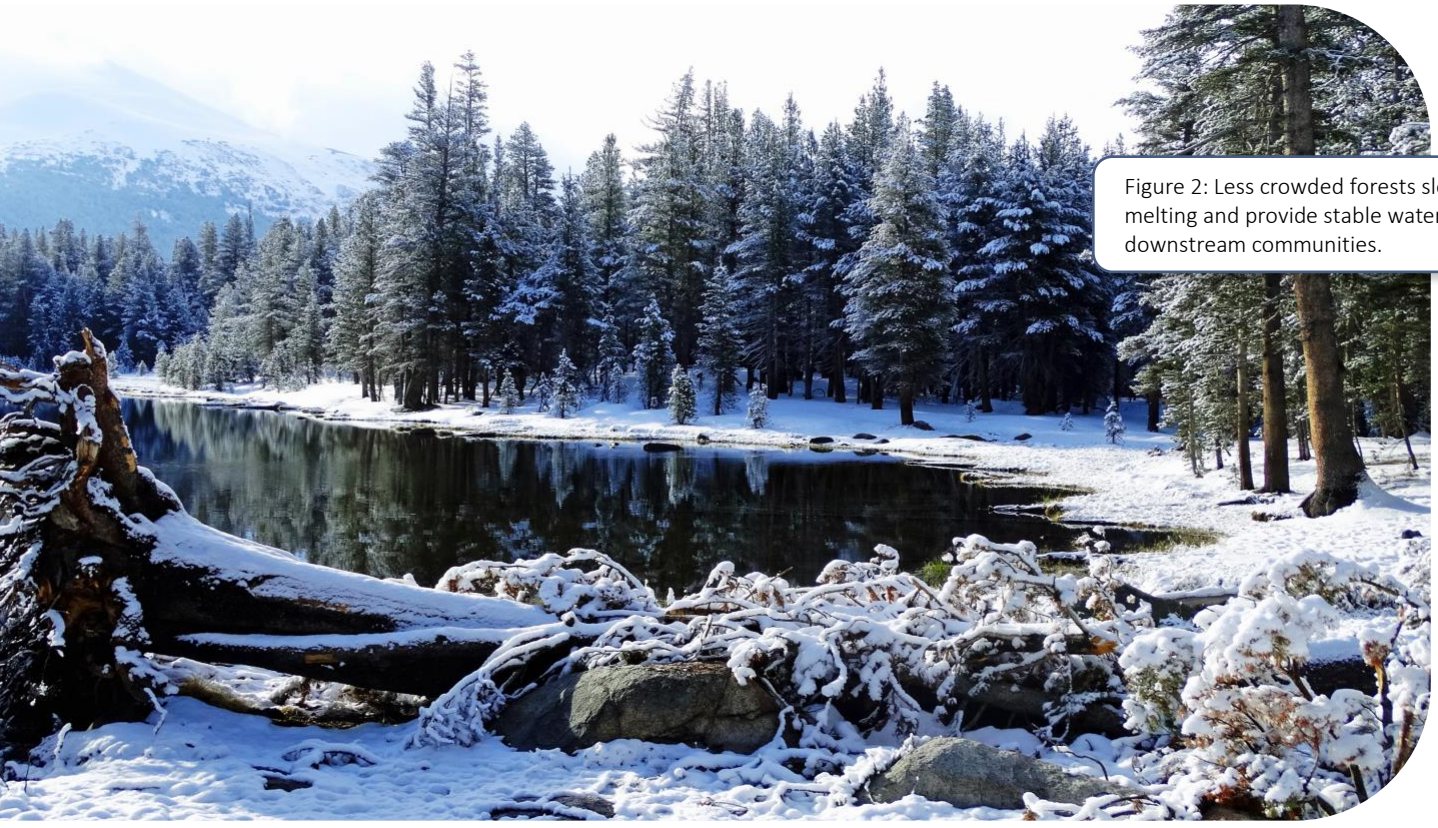


Figure 2: Less crowded forests slow snow melting and provide stable water supplies to downstream communities.

The Sierra Nevada also contains some of the most carbon-dense forests in the United States thereby providing a significant service in storing carbon and advancing California towards its greenhouse gas (GHG) reduction goals laid forth by AB-32 in 2006.[xx] The Nature Conservancy recently conducted an analysis published in the *Proceedings of the National Academy of Sciences*, indicating that California's natural and working lands, through a suite of different management, restoration, and conservation activities, can contribute up to 17% of the GHG reductions that the state needs to meet its 2030 reduction goal.[xxi]

Forest management that encourages healthy, resilient growth and treats dead and dying trees as value-creating resources can maximize the state's carbon capture potential.

Forest management that encourages healthy, resilient growth and treats dead and dying trees as value-creating resources can maximize the state's carbon capture potential.

In 2017, 1,248,606 acres of the combined annual total of CALFIRE and US Forest Service land was burned by wildfire.[xxii] In a matter of days, the 2017 Tubbs Fire in Sonoma and Napa Counties became the third deadliest fire in California history, causing 22 deaths and demolishing over 5,600 structures.[xxiii] The 2013 Rim Fire in Tuolumne County was the fourth largest fire in the state, burning over 257,000 acres. Maintaining forest health and encouraging fire resiliency protects human lives, infrastructure, air quality, and public health just as much as it promotes carbon sequestration.

As regulators of ecological health and the quality of air, water, and soil, forests offer vital co-benefits that communities rely upon in both urban and rural communities.[xxiv] The Mokelumne Environmental Benefits Program values a healthy headwater forest at $224,260,250 based on benefits provided including structures saved, carbon captured, and merchantable timber from restoration among others.[xxv] However, the study does not include money saved from wildfire suppression costs, consequential disaster recovery costs like mudslides, the loss of jobs and economic streams, or the value of habitat function.

Climate change, shifting hydrologic patterns, increasingly dense and unhealthy forests, and rapidly growing human populations are likely the most pressing causes of declining ecosystem health.[xxvi] Forests provide ecosystem services that are often spread out or not sufficiently recognized, resulting in underinvestment in initiatives that maintain their health and rural communities shouldering a disproportionate share of the burden.[xxvii] Investments that steward forests in rural regions are crucial to ensure the continuation of reliable ecosystem services.

A Brief History of California's Forest Management Practices

Fires play an important role in the health of our ecosystems by initiating critical natural processes to remove dead and decaying matter and help restore healthy vegetation levels. Prior to European settlement, between 4.5 and 12 million acres of land burned annually in California, compared to only 320,000 acres that burned annually between 1950 and 2008.[xxviii]

After the turn of the 20th Century, suppressing wildfire became a priority in order to protect agricultural land, buildings, and human life. Public education campaigns from the United States Forest Service (USFS) used slogans like Smokey Bear's famous line "Only you can prevent forest fires," which helped strengthen the success of this message.[xxix]

As a result, grass, shrubs, and other small trees densified through the following decades. These grew into taller ladder fuels like those in Figure 3, bridging the gap between the forest surface and tree crowns and giving surface fires a way to climb higher and ignite the forest canopy. While surface fires improve forest

health by removing ladder fuels and reducing plants' competition for water and other nutrients, crown fires often devastate forest ecosystems by killing great quantities of larger and older trees and sterilizing soil.[xxx]

Figure 3: Overcrowded forests increase the risk of forest fire and tree mortality from pests. In 2017 it was estimated by the US Forest Service that there are roughly 124 million dead trees in California.

Pervasive drought conditions over 2012-2016 have further impacted forest health, increasing tree mortality rates due to the lack of water and increasing susceptibility to pest infestation and other diseases. As a response, Governor Jerry Brown formed the statewide Tree Mortality Task Force in 2014 through Executive Order B-36-15 to create a path forward to address the epidemic of trees dying from drought and disease. At the time, USFS estimated that there were 22 million dead trees in California, with "tens of millions more" in the process of dying.[xxxi] Updated estimations in April of 2017 increased these numbers to 102 million dead trees since 2010, demonstrating the growing size of the problem.[xxxii] The surplus of dead trees increases fuel loads in California's forests, significantly increasing the risk of high-intensity wildfires that are difficult to control and therefore the most dangerous to lives, communities, and critical infrastructure. California wildfires in 2017 continued to demonstrate the urgent need for proper forest management to reduce the risk of more frequent and intense wildfires. The California's 2017 Climate Change Scoping Plan acknowledges, based on recent trends in California, that an estimated 150 million metric tons of carbon, or approximately 550 million metrics tons of carbon dioxide, were emitted from California's landscapes between 2001 and 2010 – largely due to wildfire.[xxxiii] This level of emissions is equivalent to one year of greenhouse gas emissions from over 117 million cars.[xxxiv]

Climate Threats to Sierra Nevada Ecosystems

Communities throughout California are already experiencing the impacts of climate change, which are projected to accelerate and exacerbate existing natural and societal risks over the next century.[xxxv] This translates to more extreme and prolonged droughts, rainfall and erosion events, heatwaves, wildfires,

and water source reductions.[xxxvi] Each of these impacts will drastically alter Sierra Nevada ecosystems and the communities that rely upon them. Climate change is not responsible for any single event but rather increases the severity and frequency of existing risks. The past two years exemplify the type of economic, social and environmental impacts we can expect to see in California's future:

- The winter of 2016-17 was the wettest year on record for California, contributing to the failure of various infrastructure across the state. One such example was the near-disaster at Oroville Dam where two spillway failures led to the evacuation of about 190,000 people and cost $870 million[xxxvii] to repair. Rapid increases in reservoir volume and sediment combined with the aging dam led to these failures.[xxxviii] Other impacts included major flooding, mudslides, and road surface failures.
- The extreme heat wave of 2017 broke hundreds of heat records across the American Southwest including many in California. This included record-breaking temperatures and consecutive extreme heat days for coastal, valley, forest, and mountain communities. This heatwave put stress on public health, energy infrastructure, and wildfire containment efforts.[xxxix]
- The 2012-2016 drought in California prompted a three-year state of emergency due to low levels of precipitation, snowpack accumulation, and groundwater recharge. As a result, many reservoirs were near depletion and groundwater basins in critical overdraft, leaving them vulnerable to future drought events due to slow groundwater recharge rates. Significant subsidence was also noted across California during this period in over-drafted groundwater basins.[xl]

Climate change poses a profound threat to California as it reaches all communities, particularly vulnerable and low-income populations. The dependence of Californians on Sierra Nevada forests and watersheds for water supply, air quality, carbon sequestration, and various other ecosystem services highlights the importance of taking a holistic, landscape-level approach in order to protect and enhance these services.

Increased Extreme Rainfall Events

Climate change is projected to alter historic precipitation patterns, resulting in extreme rainfall events that can have severe implications on water infrastructure and natural processes. Extreme rainfall events are predicted to increase in frequency and magnitude over the following century.[xli] Between typical months of rainfall—December, January, and February—rainfall percentages are predicted to rise 31.6 percent in northern California, 39.6 percent in central California, and 10.6 percent in southern California, as compared to data between 1979 and 1999.[xlii] While precipitation may appear to relieve regions after dry summer months, extreme rainfall events exacerbate the frequency of flooding and surface water runoff.[xliii] In the Sierra Nevada, snowpack is not only predicted to decrease, but rainfall is also likely to increase.

Warmer temperatures combined with increased rainfall means runoff will occur earlier in the season and at faster rates, posing a challenge to manmade dam reservoirs designed to withstand a steady flow of runoff during summer months.[xliv] Moreover, streamflows, velocities, and erosion patterns are more likely to change, increasing the risk of sedimentation behind dam reservoirs.[xlv] Dam reservoirs that experience greater sedimentation buildup will lose storage capacity, lower water quality, and reduce flood protection, as made evident by the February 2017 Oroville Dam incident.[xlvi]

Extreme rainfall events and flooding can have costly and unpredictable impacts on dam reservoirs as sedimentation worsens. In addition, soil erosion from extreme rainfall events pose public health threats to water quality, food security, and flood protection. Peak floods intensify soil erosion, increasing sediment loads and turbidity which, in addition to runoff from farms and roads, can increase concentrations of pollutants in fresh water supplies downstream.[xlvii] Polluted water supplies can reduce

drinking water availability or require additional water treatment at the public's expense.[xlviii] For regions economically dependent on agriculture, soil erosion coupled with peak flooding will also stress crop productivity which is a major contributor to food and livelihood security.[xlix] As of 2014, over 700 million Californians live within 500-year floodplains, exposing them to greater flood risks as extreme rainfall events increase in frequency.[l] As California's existing infrastructure ages and becomes overwhelmed by increasing rainfall, many populations are at risk of property damage and loss of life.[li]

Decreased Snowpack

A well-documented shift in water flow and snowpack in California indicates a decrease in reliable water sources generated from Sierra Nevada headwaters. Average snowpack levels have reduced by 25%[lii] and the average springtime snowfall is expected to drop 64% by the end of the twentieth and twenty-first centuries, which will impact the Sacramento River, San Joaquin River, and Tulare Lake hydrologic regions.[liii] As the springtime snowmelt has been relied upon to supply 50%-80% of the annual flow volume in the American West, this shift will likely have widespread implications for the state's water supply, an economic loss for downstream agricultural production and upstream winter-sport industries, as well as an increased risk of public health issues for both frontline communities and lowland, downstream users of Sierra Nevada's resources.[liv]

Furthermore, streamflow from snow-dominated basins are arriving progressively earlier in the season than what has been historically observed, and rain is projected to be increasingly common in upland areas in place of snow.[lv] The amount of runoff during summer months will still decrease as the increase in rainfall is not expected to offset the loss of snowmelt.[lvi] Consequently, the state is more vulnerable to

Figure 4: Drought and unstable water contributes to farmers reducing the number of workers they hire and the amount of food they produce.

wildfires and reduced crop yields for agricultural production during drier summer months. In 2015, the estimated economic impact of the drought on California's agricultural industry totaled $2.74 billion with a loss of up to 10,100 seasonal jobs.[lvii] Decreasing snowpack levels will exacerbate the economic consequences of future drought events, which are projected to occur with greater frequency.

Dense, overgrown forested landscapes also reduce snowpack accumulation due to snowfall collection on canopies, which, when combined with a warming climate, leads to faster snowmelt and evaporation.[lviii] Snow accumulated in canopies melts faster than at ground level, diminishing its potential to contribute to the snowpack. Instead of freezing, this snow leads to increased soil moisture.[lix] As such, lingering water in the soil provides more opportunity for a denser vegetation to grow, creating less water in future months of the year that would generate downstream benefits.

Interconnectedness of Climate Impacts

California is an immensely complex system of both ecological and human communities. While each issue discussed in this paper is significant in and of itself, the combined effects can magnify the risks of climate change, emphasizing the need for a concerted effort across regions to protect California's resources and to build resilience to climate impacts.

Since 2009, California has experienced several of the most extreme natural events in its recorded history: severe drought, historically low Sierra Nevada snowpack, five of the top 20 largest forest fires in terms of acreage burned, and two years in a row of the hottest average temperatures.[lx] Within the last year, the devastation incurred by the series of 2017 October fires in over two dozen locations throughout the state pushed Governor Brown to declare a state of emergency. If not properly addressed, the compounding effects of climate change in the Sierra Nevada will incur more severe and long-lasting impacts and more frequent catastrophes to California's natural resources, built infrastructure, and the public.

Wildfires

In 2017, catastrophic wildfires caused by overcrowded forests, drought conditions, and climate change have become one of the most prevalent and disastrous threats to California's residents and critical infrastructure. While small-scale wildfire is a natural part of many forest ecosystems including the Sierra Nevada, the USFS Region 5 estimates that between six and nine million acres of their land require restoration work to prevent abnormally extreme wildfire,[lxi] which would double or triple current on-the-ground work. The threat of disease, bark beetles, drought, and overcrowded forests increases the risk of high-intensity burns, which leads to forest scarring, sterile soil, and greater erosion into waterways. These impacts are magnified by hotter climates which make Sierra Nevada summers drier and winters wetter, causing the snowpack to shrink and an early snowmelt to increase fuel loads (flammable material) and decrease water availability.

Catastrophic wildfires impair the quality and function of California's watersheds when high-intensity megafires cause total death of the forested areas that keep soil in the ground. In the aftermath of a devastating wildfire, rain storms and spring runoff can carry away the surface levels of soil that are no longer anchored in place by the roots of living grass, trees, and other plants. As a result, flash floods and mudslides can deposit large quantities of sediment into watersheds, adding particulate matter to source-water supplies and decreasing the storage capacity of dams and reservoirs.

The 2017 fires demonstrated how despite a large snowpack, early-season snowmelt led to early spring blooms, which then crisped into dry fuel loads through one of the hottest summers on record. While

some fires are inevitable and represent a healthy ecosystem, the compounding effects of bark beetle infestation, tree mortality, overcrowded forests, early spring snowmelt, and a dry summer led to a series of wildfires that destroyed over 8,400 structures with numerous deaths due to direct and indirect consequences.[lxii] In 2017, over 9,000 wildfires in CALFIRE and US Forest Service land alone burned a total of 1,248,606 acres.

One study valuing the loss of ecosystem services from the 2013 Rim Fire estimated between $100 million and $736 million in damages to services like carbon sequestration, air quality, biological control, and water regulation.[lxiii] The Sierra Nevada Conservancy estimated at least $136 million in recovery costs with no exact amount on habitat destruction, loss of income from tourism, and the destruction of working lands.[lxiv] That same year was the first time in history the USFS spent over half of its budget on fire suppression by the end of August.[lxv] The economic burden of fighting fires reduces the funds available for restoration projects and comes at a cost of lives lost, public health impacts, damage to infrastructure, and a loss of valuable ecosystem services the Sierra Nevada provides to both urban and rural communities.

Figure 5: Catastrophic forest fires in Northern and Southern California devastated several communities. The aftermath of fires leaves communities vulnerable to mudslides, unhealthy water, and poor air quality.

Another report on the 2013 Rim Fire stated that the fire released an estimated 11.4 million metric tons of greenhouse gas, which is equivalent to emissions from 2.3 million cars, or roughly the annual vehicle emissions of the City of Los Angeles.[lxvi] The reversal of carbon storing landscapes into carbon-emitting, barren, and scarred landscapes hinders the ability of California to reach its emissions reduction goals and to build resilience to future catastrophes. In addition, the Southern Fire Exchange stated that fine particulate matter from wildfire emissions contributes to cardiovascular and lung diseases including asthma, chronic obstructive pulmonary disease (COPD), pneumonia, and heart failure. An increase in fine particulate matter concentrations also led to a 34% increase in asthma-related hospital admissions when compared to pre-wildfire levels.[lxvii]

For example, nearly 40% of the 2014 King Fire burned at a high intensity, killing plants and sterilizing soil.[lxviii] Subsequent rainfall in the burn scar area deposited downed trees and topsoil into the Rubicon River which supplies water to downstream Placer County. Immediately following the fire, the Placer County Water Agency spent $8 million to repair critical water and energy infrastructure. The agency also incurred between $3-5 million in direct expenses to repair hydropower infrastructure, as well as another $3-5 million indirectly due to lost hydropower capacity.[lxix]

In 2010, scientists studied drinking water contamination following the Fourmile Canyon Fire in northern Colorado. The fire contaminated drinking water supplies used by several communities in Boulder County, Colorado. During the first precipitation event after the fire, water samples showed Dissolved Organic Carbon concentrations as high as 17 milligrams per liter, which was much higher than the standard 5 milligrams per liter concentration considered safe for drinking water. Nitrate concentrations in the water also increased substantially from 0.1 milligrams per liter to 1.3 milligrams per liter.[lxx]

Warmer, wetter winters, coupled with long, dry summers, provide ideal circumstances for forest fire. Increased rainfall spurs the growth of biomass, and drier, longer growing seasons increase the amount of flammable material. Additionally, forest overgrowth from fire suppression has increased competition for resources, leaving trees vulnerable to pests. Outbreaks of insect-driven tree mortality in the state grew to more than 4 million acres in 2016, a nearly five-fold increase from the number of acres reported in 2014.[lxxi] Warm temperatures also reduce the time between reproductive cycles of many pests, putting more trees at risk of dying. Tree mortality from both drought and pest attacks increases the flammable material for wildfires and could have major economic consequences for California's water supply, recreation, and air quality. Decreasing the forest structure's density should be prioritized in order to preserve healthy forests and minimize the impact of future disasters.

Compounding Water Supply Issues

The Sierra Nevada's declining ecological health negatively impacts California's primary water source for both urban and rural users. Rising temperatures alone will require traditional harvests in California to use more water in order to compensate for a loss in soil moisture.[lxxii]

Threats to critical water supplies will negatively impact hydropower production and drinking, agricultural, and municipal water use for downstream users.

> Threats to critical water supplies will negatively impact hydropower production, as well as agricultural, municipal, and household water use for downstream users.

While the recent drought was officially declared over by Governor Brown in 2016, residual effects in the Sierra's over-stressed and declining forests remain. Additionally, future weather patterns are projected to include prolonged periods of decreased rainfall, which will exacerbate current challenges in integrated water resources management. Headwater forests are also highly vulnerable to wildfire.

Burned watersheds are prone to increased flooding and erosion, which impairs reservoirs, water quality, and drinking water treatment processes through rising costs,[lxxiii] and can reduce water storage capacity and impact the timing of water flow. Although high-volume flows might be seen during the winter, the lack of water dispersion during the summer and fall especially impacts hydropower energy generation, agriculture, recreation, and the proper function of other environmental services.

Figure 6: Dangerous mudslides struck Montecito following the severe wildfires in Southern California. In addition to destruction of homes, erosion and mudslides can impair reservoirs and water quality.

During periods of drought, groundwater use will likely intensify, which can result in a permanent loss of storage capacity and damage to infrastructure, including flood management and transportation facilities.[lxxiv] The compounding effects of a low snowpack and dry seasons will concentrate contaminants such as heavy metals, industrial chemicals, pesticides, sediments and salts. Once contaminated, groundwater can be difficult to clean and may not be suitable for its intended use.

The water management community has invested in, and depends upon, a system based on historical snowpack conditions.[lxxv] The California Water Project represents the scale at which California relies on Sierra Nevada watersheds to be distributed to lowland, downstream users. However, in 2014, the drought and record low 5% snowpack decreased water supply levels enough to shut off all water allocation throughout the state in order to protect remaining water supplies.[lxxvi]

Furthermore, more frequent and severe floods in California are expected to contribute to a host of public health concerns including water quality impacts, safety issues, property damage, displacement, and post-disaster mental health issues.[lxxvii]

With climate change impacts compounding the problems of California's water supply, economic prosperity, and public health, a comprehensive strategy across the urban-rural transect is needed to properly manage Sierra Nevada natural resources.

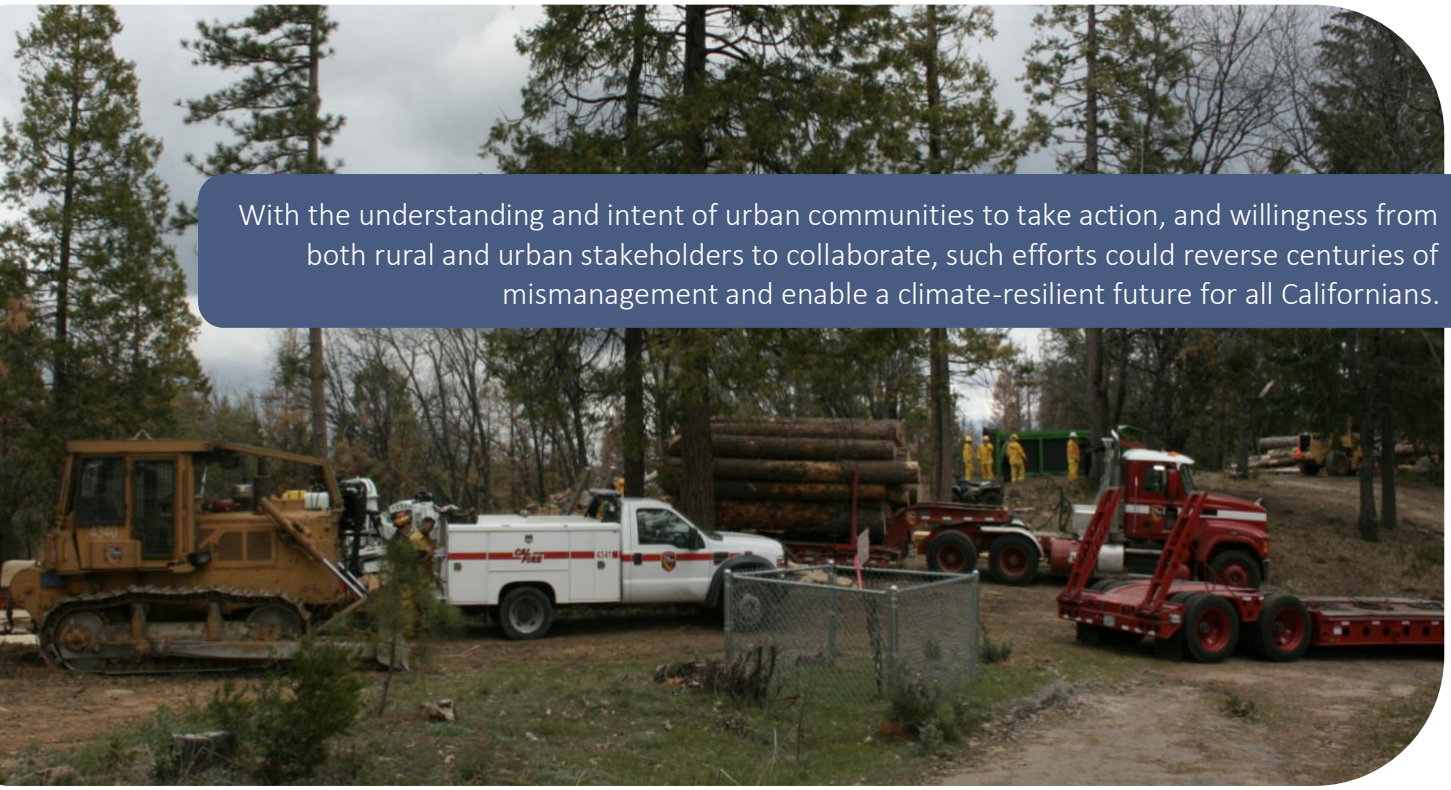
A concerted effort among urban and rural stakeholders is essential now more than ever in order to safeguard California's ecosystems and communities, particularly the state's most vulnerable and under-resourced populations.

Active Forest Management for a Resilient Future

Over the course of decades, the lack of prescribed burns and poor management techniques in California's forested watersheds unintentionally led to the ailing forest ecosystems present today. Each year, these conditions add to California's wildfire risk, as well as the size and intensity of fires. Wildfire suppression now consumes the majority of dollars spent by the California Department of Forestry and Fire Protection (CAL FIRE) and the US Forest Service (USFS)—about $2 billion a year, versus just $100 million for active forest management.[lxxviii]

Continuing to under-fund active management threatens watersheds, critical habitat, air quality, public health, carbon capture, and the myriad of other ecosystem services that depend on healthy forests. Large, damaging wildfires caused by unhealthy forest ecosystems profoundly impact upland areas of the state, dampening local economies that rely on recreation and tourism, as well as threatening lives, property, and critical infrastructure. Downstream communities are similarly affected by the repercussions of wildfire smoke, the cost of addressing dwindling water supplies, the loss of open space and recreational opportunities for their residents, and other ecosystem benefits like air and water quality and carbon capture. These impacts are exacerbated by increasing temperatures, changing precipitation patterns, decreasing snowpack, and prolonged droughts. Furthermore, rising temperatures and a growing population will increase the demand for water, especially in agricultural regions. As demand for water increases, smaller utilities that are geographically isolated will also face significant challenges funding safe water supplies.[lxxix] The stress on ecosystem services combined with inadequate forest management poses a serious threat to California's public health and economy.

Nevertheless, as future publications in this urban-rural white paper series will explore, many solutions and opportunities for urban and rural communities to collaborate exist. Recently published reports, including the Little Hoover Commission's *Fire on the Mountain* (2018) and the Legislative Analyst Office's *Improving California's Forest and Watershed Management* (2018), provide additional in-depth assessments and recommendations for addressing the current and historic management regimes of Sierra Nevada natural resources. With the understanding and intent of urban communities to take action, and willingness from both rural and urban stakeholders to collaborate, such efforts could reverse centuries of mismanagement and enable a climate-resilient future for all Californians.



With the understanding and intent of urban communities to take action, and willingness from both rural and urban stakeholders to collaborate, such efforts could reverse centuries of mismanagement and enable a climate-resilient future for all Californians.

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Figure 1: Wondermondo

Figure 2: Wikimedia Commons

Figure 3: USDA

Figure 4: Al Jazeera America

Figure 5: CAL FIRE

Figure 6: The Santa Barbara Independent

Figure 7: CAL FIRE