State of the Forest Report

FOR THE SAN JUAN NATIONAL FOREST | 2019

Drought in Colorado's Forests

TREES GET DEHYDRATED TOO

FROM THE FOREST TO YOUR FAUCET

FORESTS AFTER FIRE

Mountain Studies Institute
SAN JUAN MOUNTAINS COLORADO

TABLE *of Contents*

Asubalpinefirgerminatesnextto an Engelmann spruce cone

This report was produced in partnership with:

ACES
Aspen Center for Environmental Studies

Cover: Cracked and dry soil in the Colorado River Delta as a result of persistent drought and over use of the river. Photo: Pete McBride

Science & Collaboration in the San Juan's

Welcome to the San Juan Forest and Watershed

To begin, I'd like to express our upmost gratitude to the Aspen Center for Environmental Studies (ACES) for their efforts to produce important educational materials that increase community literacy about the health of local forests and watersheds. Their efforts are smart, engaging and accessible.

We appreciate their willingness to partner on this State of the Forest Report, which aligns so well with Mountain Studies Institute's (MSI) core value of producing and sharing "science you can use" with communities in the San Juan Mountains. Since 2002, MSI has worked to empower communities, managers and scientists to innovate solutions through mountain research, education, and practice.

One of the sustaining premises of our organization, which you'll see come to bear in the pages ahead, is that collaborations among researchers, educators, and policy makers with an interest in the San Juan Mountains and other mountain systems worldwide can provide increased knowledge and understanding of mountain environments and communities and the issues that affect them.

Why focus on mountain ecosystems? Aside from the deep and abiding love we share for the place we choose to call home, there is international recognition that mountains are fragile environments, vulnerable to global climate change, soil erosion, watershed and forest degradation, fires, urban encroachment and other human impacts. We rely heavily on mountain ecosystems for resources. The Colorado River Basin is a perfect example of the way our water resources are concentrated in mountain ecosystems: less than 20 percent of the land area of the basin is within Colorado, but 70-75 percent of the river's total flow originates in the mountains of the State.

Like mountains, or rather, as part of mountain ecosystems, forests play a critical role in overall ecosystem health. They store and filter water, provide habitat, promote biodiversity, and mitigate anthropogenic climate change. And, forests are also made uniquely vulnerable under future climate scenarios as things like fire, insects, and disease become more threatening.

This connectedness—of ecosystems to one another and our communities to them all—tends to come into sharp focus during extreme or out-of-the-ordinary events.

In 2015, the Gold Kind Mine above Silverton, Colorado released three million gallons of acid mine drainage into the Animas River. Communities from Silverton to Farmington and well beyond were struck by the sheer volume, concerned about the electric orange of the river, and nervous about what it meant for a resource they rely on and care about. We monitored the river before, during, and after the spill to bring the community current, scientific information about changes in the river. While the spill brought the impacts of acid mine drainage to the forefront of conversations throughout the watershed, we were conducting science to understand the health of the river, as well as the natural minerology and the impacts of mining at the headwaters, long before the spill and will continue long after, because our concerns about the health of our watershed extend well beyond a single incident.

This year, the 416 Fire burned in the Hermosa Wilderness of the San Juan National Forest. The 2018 drought that set the stage for the fire had everyone on the edge of their seats well before the flames ignited. Because the role of MSI is to produce and provide science that helps communities understand current conditions and prepare for future ones, we responded to 2018 drought conditions by hosting a Forest and Fire Learning series to help community members understand the relationship between forests and fire, and the role climate change has in altering that dynamic. Following the fire, we headed straight to the river to monitor impacts of post-burn flooding on aquatic life. We will continue our monitoring and education efforts well into the future so we can better understand both the positive and negative impacts of fire, document restoration (both natural and assisted), and help the community

better plan for and mitigate against future wildfire.

During both the 416 Fire and the Gold King Mine Spill, MSI relied on science to bring our communities together around shared concerns and goals. We hope you find this year's State of the Forest Report provides just that.

And we hope you'll join us to continue connecting across boundaries (arbitrary and otherwise) to better understand, manage, and protect our local watersheds and the forests that sustain them. We look forward to learning with you and from you.

In the spirit of collaboration, education, and science,

Marcie Demy Bidwell
Executive Director, Mountain Studies Institute

EXECUTIVE *Summary*

I met Adam McCurdy of the Aspen Center for Environmental Studies (ACES) at a gathering of collaborative groups in Colorado and he shared the ACES State of the Forest Report with me. As you'll come to see, it's an impressive publication that covers a lot of ground. The report inspired conversation, and Adam and I set to comparing notes about our respective home geographies—I call the San Juan Watershed home and he makes his stead in the Roaring Fork Valley. It was a valuable exercise. Issues of forest health are not contained within geographical, social, or political boundaries and we can learn from the issues our neighboring geographies are squaring up against.

Throughout Colorado, communities large and small are embedded within a patchwork landscape of public, private, and Tribal lands. Lands are managed by United States Forest Service, Colorado State, Bureau of Land Management, private entities, and several Native American Tribes. But the issues that impact our shared resources rarely, if ever, pay heed to these boundaries. Wildfire, insects and disease, drought, and flooding are all especially good at hopping the fence with little consideration for who manages the land. For exactly this reason, when we set out to improve the health and resiliency of local watersheds, it is critical that we acknowledge our connectivity and engage multiple owners to effectively promote and develop cohesive, multi-faceted management strategies.

Partnerships that strive to work across boundaries can be tricky, and we run up against obstacles all the time. But they're also profoundly important. In the San Juan National Forest of southwest Colorado, three collaborative groups of varying stages come together to inform management and attempt to build resilience across boundaries. You can read more about these partnerships in the "results" section at the back of the publication.

The critical nature of partnerships and the immense value in lessons learned across arbitrary boundaries is exactly why we're so excited to partner with ACES for the 2019 State of the Forest Report for the Roaring Fork Watershed and San Juan Forest and Watershed. The folks at ACES have built an amazing storytelling and educational tool, and we're fortunate to ride their coattails in the co-production of this year's report. This is the first year we have co-produced this report, and it's also the first time that the State of the Forest report focuses on a single issue: the relationships between forests and water. The water year in 2018 made the issue particularly pertinent, especially down here in the southwest corner of the state. But as is often the case in forest and watershed health, we found it impossible to untether issues of beetle and climate and fire and drought from one another, and water was the common thread.

As you'll come to find, these reports are similar in many ways. They focus on the same topics but, in the ACES tradition, each report hones in on local forests. The distinct forests where we live are unique in many ways, but drought, insects, wildfire and climate change impact us all. In the co-production of this report, we learned from each other's experiences to better understand our own. We hope you'll learn something, too.

Thank you for reading

AARON KIMPLE

MSI Forest Programs Director

A Chinook helicopter drops water on the Lake Christine fire to protect power lines. Photo Pete McBride

Photo by Martell Crump, Coconino National Forest Service

The 416 Fire burning on the ridge near US Highway 550. Photo Michael Remke.

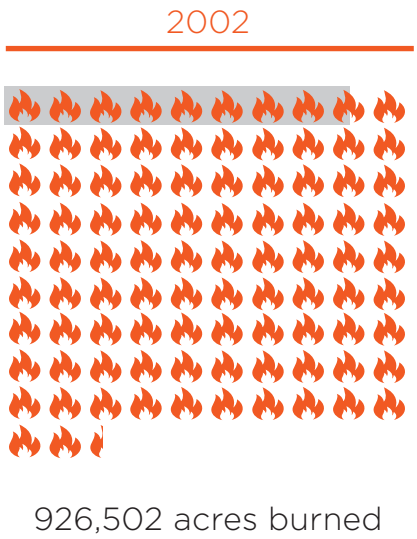
Wildfire is a natural and necessary part of many ecosystems. On an ecosystem timescale, the disturbance caused by fire can increase available nutrients, spur regeneration, and promote diversity. On a human timescale, fire can threaten our homes, destroy places we love, fill skies with smoke, and blacken rivers. For the majority of the 20th century, we prioritized the human timescale by striving to put out every wildfire. But this option has proven to be unsustainable. For forests historically adapted to frequent fire, the increase in fuels from a policy of fire suppression means fires burn hotter with more severe effects to vegetation, soils, watersheds, and wildlife. In addition to impacts from suppression, climate change is making fire more common and less predictable across forest types.

More than anything else, wildfires are driven by weather and climate. During extremely hot and dry periods, aggressive forest thinning or large-scale fire breaks may be futile in stopping a fire driven by high winds. Climate change is making hot and dry conditions more common. Conditions that might have only happened once every 25-50 years are now occurring every ten years.[1] Higher temperatures also mean less spring snow and earlier snowmelt (see Forest at the Headwaters p. 18-21), increasing the risk and duration of wildfires.

In Colorado, most wildfires occur between spring snowmelt and the start of summer monsoons. All ten of Colorado's largest wildfires occurred during this time period. In many years, snow on the ground keeps water in the soil until the monsoons come. In years with low snowpack or early snowmelt, there is a dry period between when the snow melts and monsoons begin. During 2018, low snowpack and late monsoons created the perfect recipe for higher fire danger.

The conditions in the late spring and summer of 2018 led to the largest wildfire season in Colorado since 2002. Fires of varying size and intensity burned in all areas of the State. The largest was the Spring Creek Fire which burned 108,000 acres, making it the third largest recorded wildfire in Colorado history and the most destructive of 2018. It burned more than 140 homes and damaged numerous others.

WILDFIRE IN COLORADO (ACRES BURNED)



2018 was Colorado's worst fire year since 2002, both significantly surpassed the average year over that time period

> "Without nearby seed sources, areas that burn can take decades to recover to their previous state."

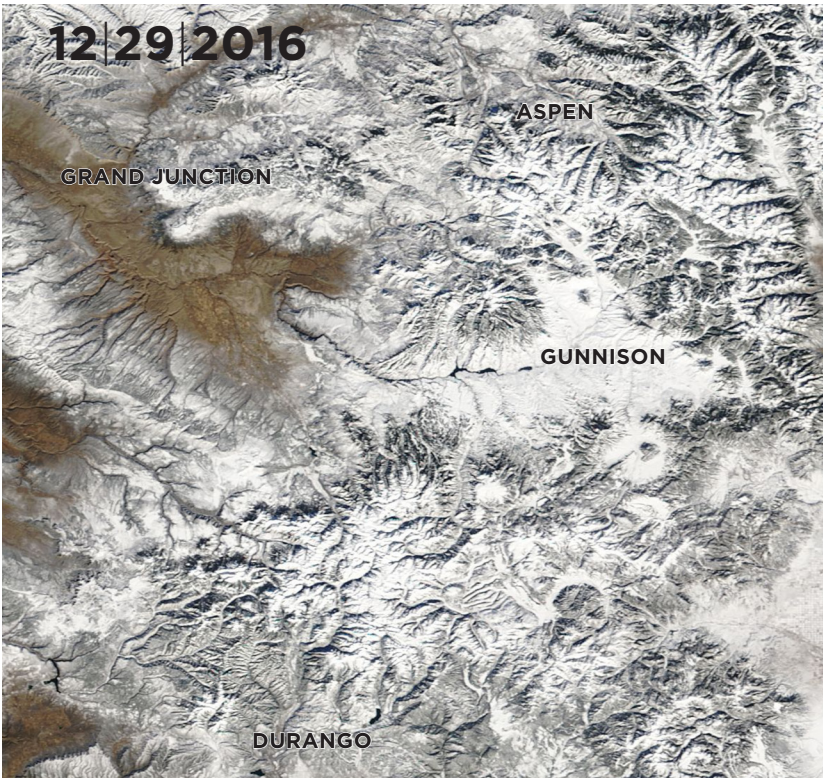
The 416 Fire

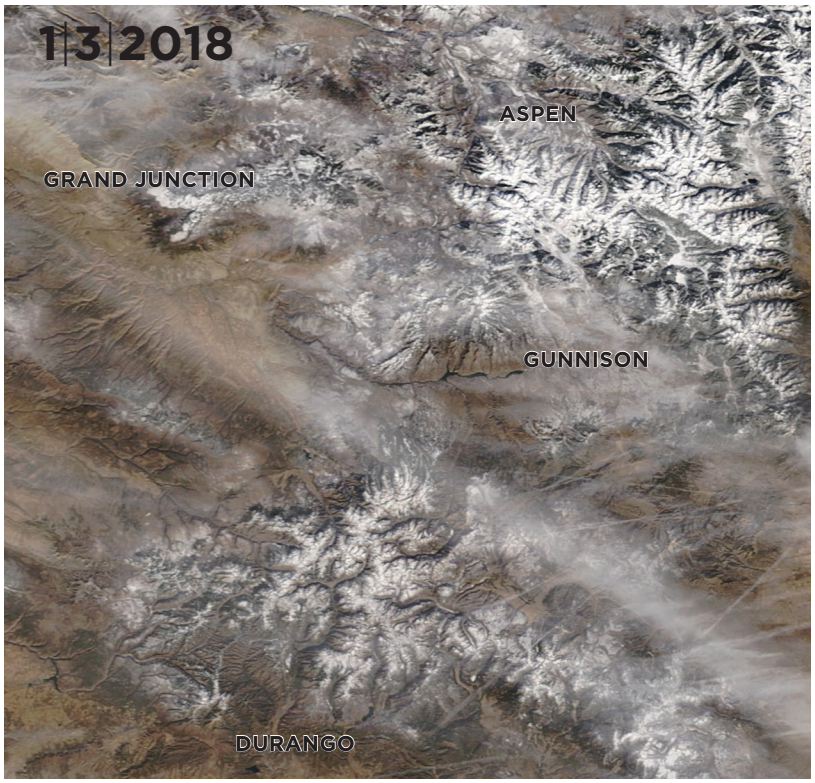
Between June 1 and the end of July 2018, the 416 Fire burned nearly 55,000 acres of the San Juan National Forest. While the cause of the fire remains undeclared, conditions on the ground made local forests highly vulnerable.

For many living and working in the area, the 416 Fire brought back memories of the Missionary Ridge Fire which burned over 70,000 acres in 2002. However, while both fires occurred during drought years with extremely low snowpack, high temperatures, and extended fire seasons, the 416 Fire did not take lives or burn homes. In many ways, the 416 returned fire to a landscape that traditionally saw it more often, and that relies on fire to maintain forest health and resilience.

The 416 Fire was not without impacts. Local businesses struggled to navigate road and Forest closures, and a region-wide decrease in tourism has had lingering effects. Further, when the monsoons arrived in mid-July, debris from the 416 burn scar flowed into Hermosa Creek and Animas River, causing significant fish mortality and structural damage.

Because the burn severity of the 416 was mostly moderate and areas of high-severity burned in patchlike patterns, forest managers are keen to let natural restoration occur. Trees that weren't killed by the fire will provide seed sources for the next generation of forest, and shrubs like gamble oak will return quickly, restabilizing soils and establishing critical groundcover and habitat. In the years ahead, meadows established by the fire will become a hotspot for diverse wildlife. Both old and new trails will open, and fish will return to the both Hermosa Creek and the Animas River. ❊

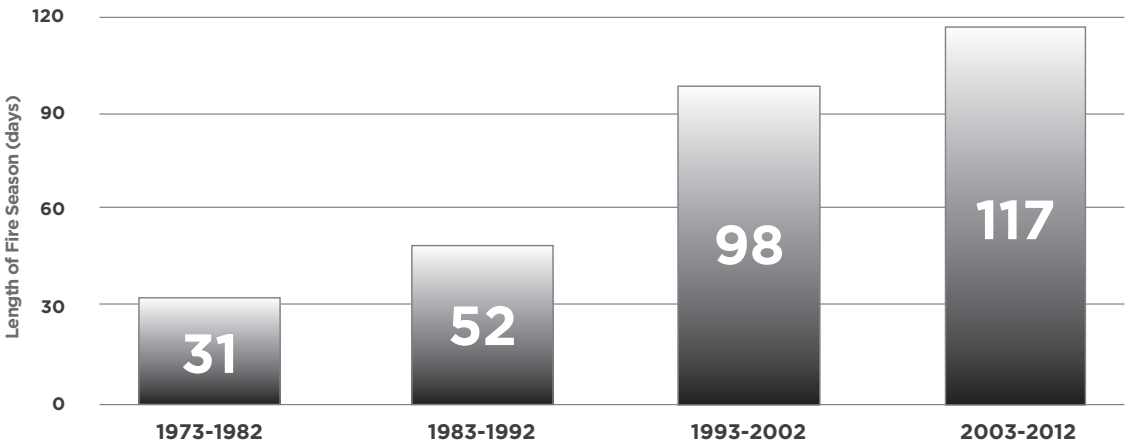




Satellite images compare Western Colorado snowcover during the '16-'17 and the '17-'18 winters. At the time these photos were taken '16-17 was slightly above average and '17-'18 was significantly below.

Human caused climate change is already influencing Colorado's forests in profound ways. Since the 1970s, year-round temperatures in Colorado have risen an average of two degrees Fahrenheit.[1] While there is no clear trend in annual precipitation in Colorado since the 1970s, the last 20 years have included several severe drought years and drier overall conditions.[1] The link between this period of lower precipitation and climate change has not been established. However, *when* we receive water during the year and *how* we receive it (more rain vs. snow) has and will continue to change. This coupling of warmer year-round temperatures and changes in water availability has significant

SOUTHERN ROCKIES FIRE SEASON (DAYS)



The length of fire season in the Southern Rockies (Rocky Mountains in Colorado, southern Wyoming, northern New Mexico, and eastern Utah) has increased since 1973. This is primarily a consequence of earlier spring snowmelt, higher temperatures in the spring and summer, and increases in human ignitions.[13]

implications for the future of forests in Colorado, specifically when it comes to wildfires.

The 2018 water year (October 2017 - September 2018) brought into focus many of the concerns and challenges that warming climates pose for forests and watersheds. Across Colorado it was one of the driest and warmest years on record, with southern Colorado being especially dry. The San Juan Mountains (Dolores, San Miguel, Animas & San Juan watersheds) received 44% of their average snowpack. Between April and September, the Animas River dipped below historic low daily streamflow a number of times, based on the 100+ year USGS record. The Roaring Fork Watershed had 70% of average snowpack.

On its own, drought poses challenges to forest vegetation and fauna, as well as for communities that rely on them (see Low Rivers & Thirsty Trees p. 14-17). Together with unusually warm temperatures, these "hot droughts" exacerbated what would have been a very poor runoff year due to low precipitation and snowfall. And, as it turns out, calling 2018 a "drought" might be an incomplete description. Drought implies a short-term deviation from the norm. On the other hand, "aridity" refers to a more permanent transition towards a dryer climate. That much of the Colorado basin is arid is not new information, but the consistent shift toward higher temperatures and increased dryness is what some researchers are calling aridification or "a period of transition to an increasingly water scarce environment".[2]

Given this shift, it isn't surprising that the summer of 2018 goes on the chart with 2012 and 2002 as some of the largest wildfire years in the state's recorded history (see Fire Update on p. 8-9). This shift in wildfire regimes and climate require the attention and action of land managers, politicians, and private citizens alike. ❊

> "Across Colorado 2018 was one of the driest and warmest years on record."

DURING THE 2018 WATER YEAR*

The Animas River reached near-record low flows of less than 100 cfs

The average temperature in Pitkin County was **4 degrees above average**, the highest in over **80 years**

Peak snowpack was **52% of average**

Insects and diseases affected **1.9% of our forest**, well below the average of 6%

Precipitation in La Plata County was **13% lower** than average

Timing of peak snowpack was **approximately two weeks early**

Spruce beetle, pictured above, are currently the most active insect in Colorado.

Insects and disease are opportunists: they take advantage of weakened and vulnerable trees. Prolonged drought and rising temperatures associated with climate change have increased vulnerability of trees to bark beetles, in particular. Between 2008 and 2015 the number of standing dead trees in Colorado increased almost 30%. [3] Much of the increase is due to attacks by insects, infection by disease, or a combination of the two. Mountain pine beetle, spruce beetle, Douglas- fir beetle, sudden aspen decline, and subalpine fir decline are all pervasive on the landscape. Over the past 20 years, populations of these mostly native insects and fungi have exploded, aided significantly by heat and drought.

Over the course of millions of years, trees and wood-boring insects have evolved together. When insects develop new ways of attacking trees, the trees in turn develop new defenses. The primary defense trees have against bark beetle is their ability to produce resin or pitch. When bark beetles burrow into the bark of a tree, the tree responds with a stream of sticky resin. Resin forces beetles out and carries chemicals which are toxic to both the beetles and the fungi they carry. During moderate and severe drought, a tree's ability to produce resin and chemical defenses is impaired, making them much more vulnerable to bark beetles and fungi.

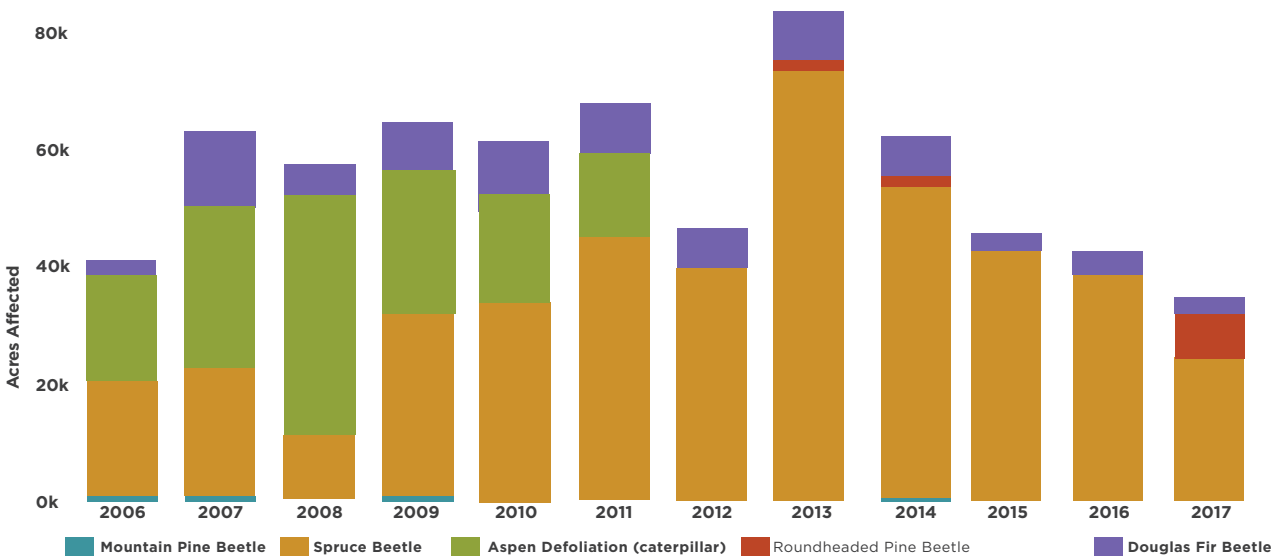
Bark beetles are always present in forests. At low or endemic levels, they attack and kill already weak trees but are often unable to impact healthy trees. During severe droughts, weak trees are more common. An increasing number of susceptible trees means bark beetles are more likely to be successful. Warmer temperatures reduce winter beetle mortality, and increase the rate of beetle reproduction.[4] Under these conditions, bark beetle populations can reach epidemic levels (aka outbreaks) and even healthy trees can be overwhelmed by mass attacks. Climate change has already made drought conditions more common, and predictions of future climate change suggest that warm and dry years like 2018 will be more frequent. These changes will lead to further bark beetle epidemics and widespread tree mortality in Colorado's coniferous forests.

SJNF Summary

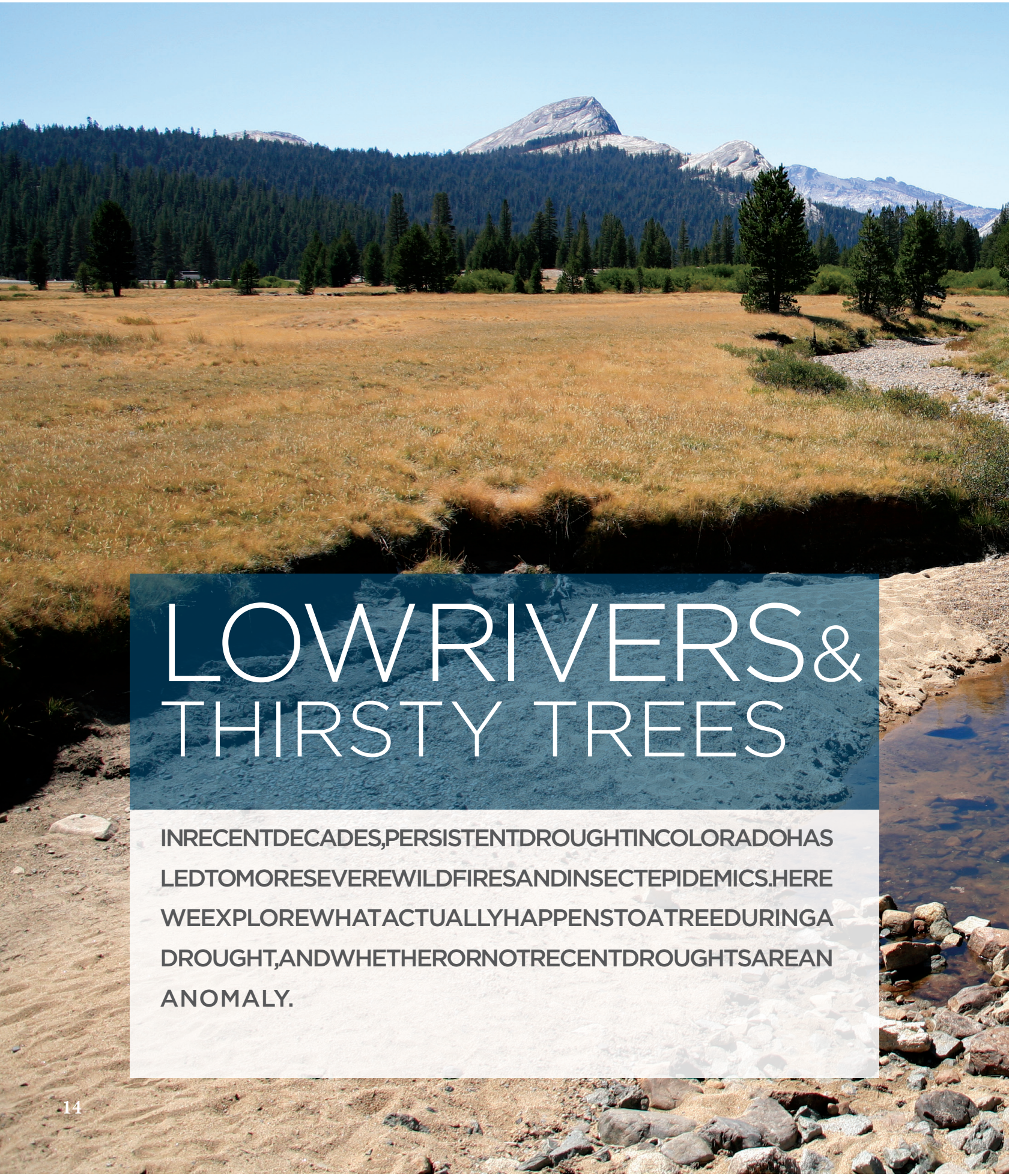
In 2018, the predomint impact on the San Juan National Forest continued to be the Spruce Beetle on Englemann and occasionally Colorado blue spruce. In Archuleta County, impacts slowed slightly while Spruce Beetle kill in neighboring San Juan and La Plata Counties increased. Since 1996, Spruce Beetle has impacted more than 1.84 million acres statewide. Of particular concern in 2018 was the dramatic spread of the roundheaded pine beetle in the Dolores Ranger District. Between 2017 and 2019, the impacted area grew from 11,000 to 27,000 acres - roughly 30 percent of the 90,000 acres of ponderosa forests in the District. Dan West, entomologist with the Colorado State Forest Service, attributes the persistence of the infestation to to ongoing and severe drought. ❊

> "Between2008and2015thenumberofstandingdeadtrees in Colorado increased almost 30%."

SAN JUAN NATIONAL FOREST INSECTS & DISEASE



credit: Joseph Benzel, Screening Aids, USDA APHIS ITP, Bugwood.org



LOW RIVERS & THIRSTY TREES

IN RECENT DECADES, PERSISTENT DROUGHT IN COLORADO HAS LED TO MORE SEVERE WILDFIRES AND INSECT EPIDEMICS. HERE WE EXPLORE WHAT ACTUALLY HAPPENS TO A TREE DURING A DROUGHT, AND WHETHER OR NOT RECENT DROUGHTS ARE AN ANOMALY.

Lowprecipitationandhotweatheroverthepast 20yearshasledtodroughtsacrossthewestern United States

Over the last 20 years, forests in the western United States have experienced major changes: bark beetles killed hundreds of millions of trees, wildfire burned tens of millions of acres, and disease wiped hundreds of aspen stands from the landscape. These events are part of a larger global increase in tree mortality.[5] We don't have to look hard to find recent tree mortality in the Roaring Fork Valley, whether it's sudden aspen decline on Buttermilk or Douglas fir beetle on Aspen Mountain. It's impossible to completely blame any one thing for these dramatic events, but it has become increasingly apparent that thirsty trees are at the root of the problem.

Human Dehydration vs. Tree Dehydration

We all know forests suffer during a drought, but what actually happens to a tree when it doesn't have enough water? For humans and other animals, dehydration often occurs over a relatively short period. Without water, the amount of blood in a person's body decreases, and their heart beats faster to feed their organs. Eventually, blood volume drops and the heart can no longer beat fast enough. Without blood, organs begin shutting down and a person will die. Depending on the environment and physical activity, this can happen over the course of a few hours or, at most, a little over a week.

For trees, dehydration is a very different process. Lacking the ability to move and find water, trees find water deep in the ground and store large quantities. Some trees can survive months or even years without rain but when deprived of water long enough, they will die.

The roots of a mature tree can take up between 5,000-10,000 gallons of water over the course of a year. While some of this water is consumed during photosynthesis, most of it returns to the atmosphere through transpiration when trees "inhale" carbon dioxide and "exhale" oxygen. To conserve water, trees stop absorbing carbon dioxide and photosynthesis comes to a halt. Trees that use this strategy will eventually suffer from carbon starvation, the depletion of stored carbohydrates. If carbon starvation continues for long enough, a tree will no longer have the resources to defend itself from attacking insects, fires, and fungi.

Other trees will continue to photosynthesize using whatever water is available. Eventually the xylem vessels, which transport water through the tree, will no longer be able to pull any water through the root system. Without water, xylem cells develop air bubbles, a process called cavitation. Once an air bubble forms, the xylem can no longer transport water from the roots up the trunk to branches and leaves. Rather than

> "We must consider that recent droughts are not part of a normal cycle but are the product of human-caused climate change."

Sudden Aspen Decline on Buttermilk Ski Area is a visible symptom of persistent drought and high temperatures

carbon starvation, these trees suffer from hydraulic failure, but the outcome is similar and trees succumb to insects, fungi, or fires long before dying directly from drought.

Trees and the broader forest ecosystem, especially those in Colorado, are adapted to drought. But drought is a temporary condition; it is by definition a deviation from the normal or expected temperature and precipitation patterns. Tree-ring records provide a robust record of drought in Colorado going back to 1,400 AD. Over that time period, Colorado has experienced numerous droughts, some spanning multiple decades. In every case the drought eventually abates, and gives way to wetter conditions. During these periods many trees die but forests recover. If the increased rate of tree mortality is a consequence of normal drought, we can expect this to happen. We must also consider that recent droughts are not part of a normal cycle but are the product of human-caused climate change. If this is the case, a return to the conditions society and trees have evolved to is unlikely. Instead we can expect a drier, hotter western United States.

Changing Forests

What does all of this mean for forests in Colorado and the Roaring Fork Valley? Unfortunately, there are more questions than answers. How will insects be impacted by warmer temperatures and drought? Some research suggests bark beetles benefit from slightly warmer temperatures but suffer when temperatures become too high. How will trees react? Different populations of the same species can be more or less resilient to drought or high temperatures. Forests themselves have the capability of altering temperatures and precipitation, so their loss or persistence will have measurable impacts on the future climate.

The one thing we can say with high confidence is that forests around us are changing. In this 2019 *State of the Forest Report*, we explore the role of forests in sustaining Colorado's drinking water supply, the interaction of drought, forests, fires, and floods, and how forests fit into the broader conversation around climate change and drought. ❊

FORESTS AT THE HEADWATERS

WHEN WE OPEN THE TAP TO POUR OURSELVES A GLASS OF WATER, IT'S UNLIKELY THAT FORESTS ARE THE FIRST THING TO COME TO MIND. BUT WHEN IT COMES TO STORING, FILTERING, AND DELIVERING OUR WATER, FORESTS PLAY A MAJOR ROLE.

Mountainforests,liketheoneshownhere,captureand storethesnowthatmakesupalmost80%ofColorado's water supply.

Imagine it's early spring and, after being relegated to low elevations all winter, you're eager to hit the trails and get back into the high country. In the open meadow where you start, the trail is packed dirt and clear. As soon as you ascend into the first dark, forested section of the trail, the trees around you shelter the last remaining snow from sun, and suddenly you're post-holing through knee-deep snow.

From the Forest to Your Faucet

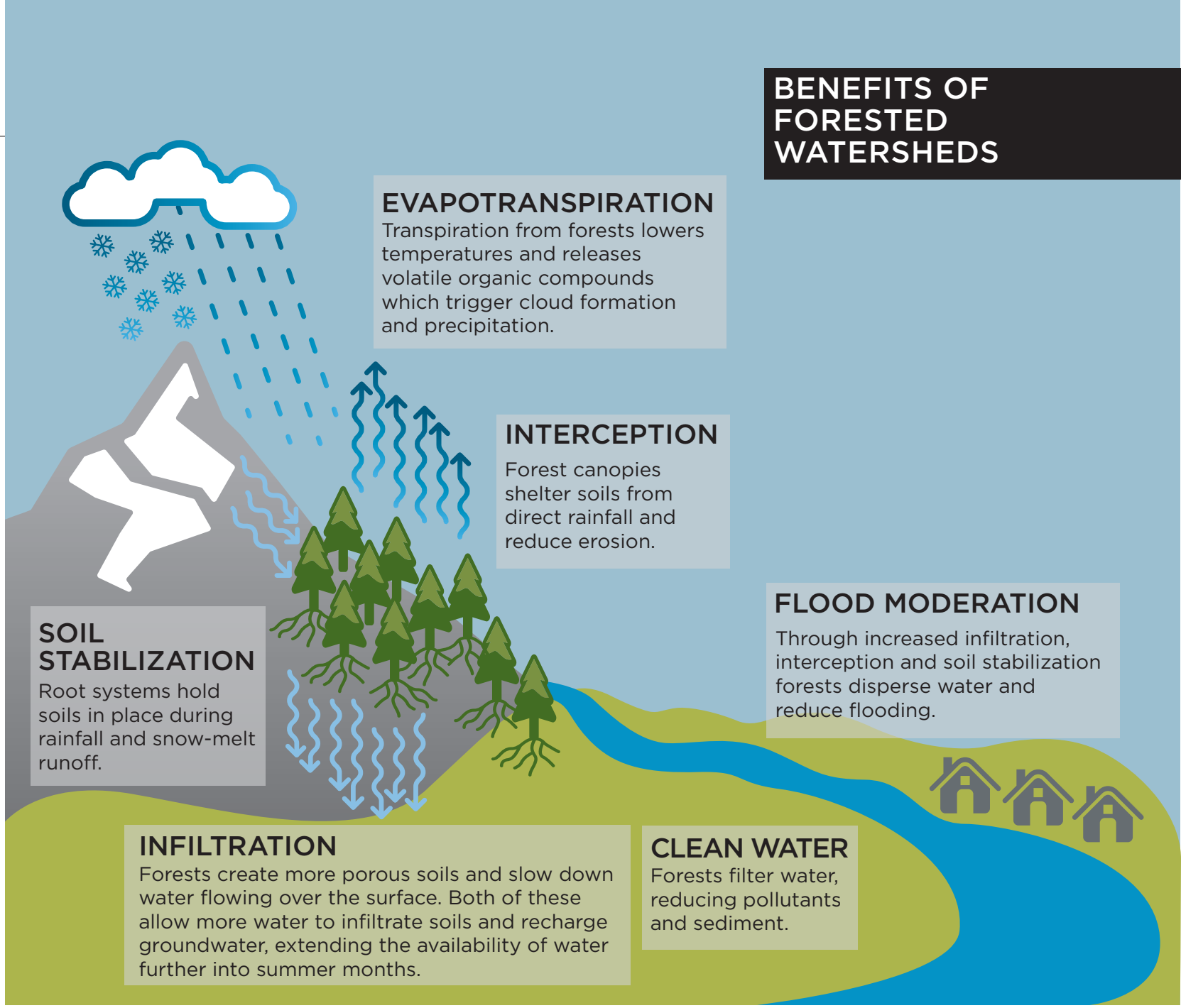
Forests play a vital role in snow storage and water quality protection. Snow stored by forests melts slowly, providing a steady supply of water to plants, animals and people. The recognition of forests as key players in the fight to conserve and improve state water supplies has been increasingly expressed through investments in forest health. In 2017, Denver Water and the U.S. Forest Service agreed to continue the work of protecting and restoring forests across the state with an investment of $33 million over the next five years.

The forested headwaters in Capitol Creek are a reliable source of clean water.

Water managers' interest in forest health shouldn't come as a surprise: forests are the source of 53 percent of US water supply (in the contiguous US) and, in the West, that number increases to 65 percent.[6] In this semi-arid part of the country where water is a critical resource, when it comes to storing, protecting and delivering that water, healthy forests play a vital role.

The Colorado River provides water for more than 40 million people, and 75% of the water in the river comes from the state of Colorado, much of it from forested watersheds.[7] Given Colorado's status as a headwaters state, forests in Colorado have profound impacts on water quality and availability for people within the state and for millions of people throughout the West and Mexico. This critical ecosystem service that forests provide is already impacted by climate change.

> "The Colorado River provides water for more than 40 million people, and 75% of the water comes from Colorado."



Adapted from "How Natural Infrastructure Supports Water Security" by World Resources Institute

Snow Reservoirs

Nearly 80% of Colorado's annual water supply originates as snow that is captured primarily on forest landscapes. A healthy forest ecosystem shades and stores snow in the winter, stabilizes hills and mountain sides with their roots, tempers the flow of water through soil, and increases the duration of water availability downstream throughout the warmer, drier months.

But as the climate changes and precipitation in Colorado falls increasingly as rain, the forest's ability to filter and store water changes. According to one climate projection, Colorado's average statewide snowpack could decline by 13 percent between 2041-2070, with that number doubling later in the century.

As increased temperatures continue to increase runoff of a dwindling snowpack, and longer growing seasons increase demand on our water supply, the role that forests play will be an important study area.

FIRE, FLOOD & FORESTS

AFTER A FOREST BURNS, BOTH HUMAN AND ECOLOGICAL COMMUNITIESIMPACTEDBYTHEFIREUNDERGOCHANGE,BUTNOT ALWAYS AT THE SAME PACE.

Hermosa Creek in the San Juans runs black with sediment from the 416 fire.

Inset: Heavy rain after the 416 fire produced erosion and ash flows that turned Hermosa Creek black

Recovery after a wildfire can be a long and painful process. In addition to secondary effects like erosion, places many of us hold dear are dramatically changed for the rest of our lives. After more than 20 years, Weller Lake and Storm King Mountain still bear scars from wildfire. Climate change impacts the scale and frequency of wildfires in Colorado, as well as the resiliency of forests and their ability to regenerate post-burn.

Disturbance Regime

While shifts in species composition after a fire are, to some extent, normal and expected, the rate and scale of change and the dramatic shift in species composition in the 21st century are heavily influenced by temperature and drought stresses attributed to climate change.[8] When a "disturbance event", like wildfire, moves through a forest, it resets the ecosystem. Under normal conditions, forests could come back as they were before. But drought and warmer temperatures make it hard for young trees to establish themselves and open the door for more drought-resilient ecosystems (like shrub or grasslands).

Forest ecosystem shifts happen on a time scale that is rarely in sync with the demands of human development. What might be good for the forest or a landscape over hundreds of years is rarely convenient and often detrimental to the ways we've come to rely on our forests and watersheds. We rely on water where we've built homes and need forests to burn around them rather than through them. This tension of living with and relying on forests that exist on a different timescale than we do is exacerbated by the impacts of climate change.

> "Given the impacts of climate change, forests are less likely than before to return to their pre-fire conditions."

The Response

For both human and forest communities, response to wildfire occurs in stages. Early on, before the first fires of the season ignite, humans make predictions about what kind of fire year lies ahead. We zoom in on precipitation records, identify drought trends, and assess the potential for human-caused ignitions and opportunities (like forest closures) to minimize that risk. In the forest, conditions for fire are determined by factors, like precipitation and temperature, that go back years. In a year like 2018 and the Lake Christine Fire, the moisture content of standing fuels was extremely low. A small fire was able to grow rapidly to the point where it couldn't be easily contained. The combination of drought, high temperatures, and humans made for an extremely dangerous situation.

Once a fire is burning, human response focuses on the management of the burn for the protection of communities and infrastructure. Fuels, the moisture content of trees, and weather patterns will dictate how fire moves through the forest and at what intensity it burns. In addition to trees, forest soils can undergo major changes during a wildfire, depending largely on the burn severity. The burning of litter and organic matter at intense heat turns it into a sort of waxy substance that penetrates the soil as a gas. As the air cools, it turns to a solid. This new-formed soil

Mountain Studies Institute field crews survey post-burn recovery following the 416 Fire . Photo by Anthony Culpepper.

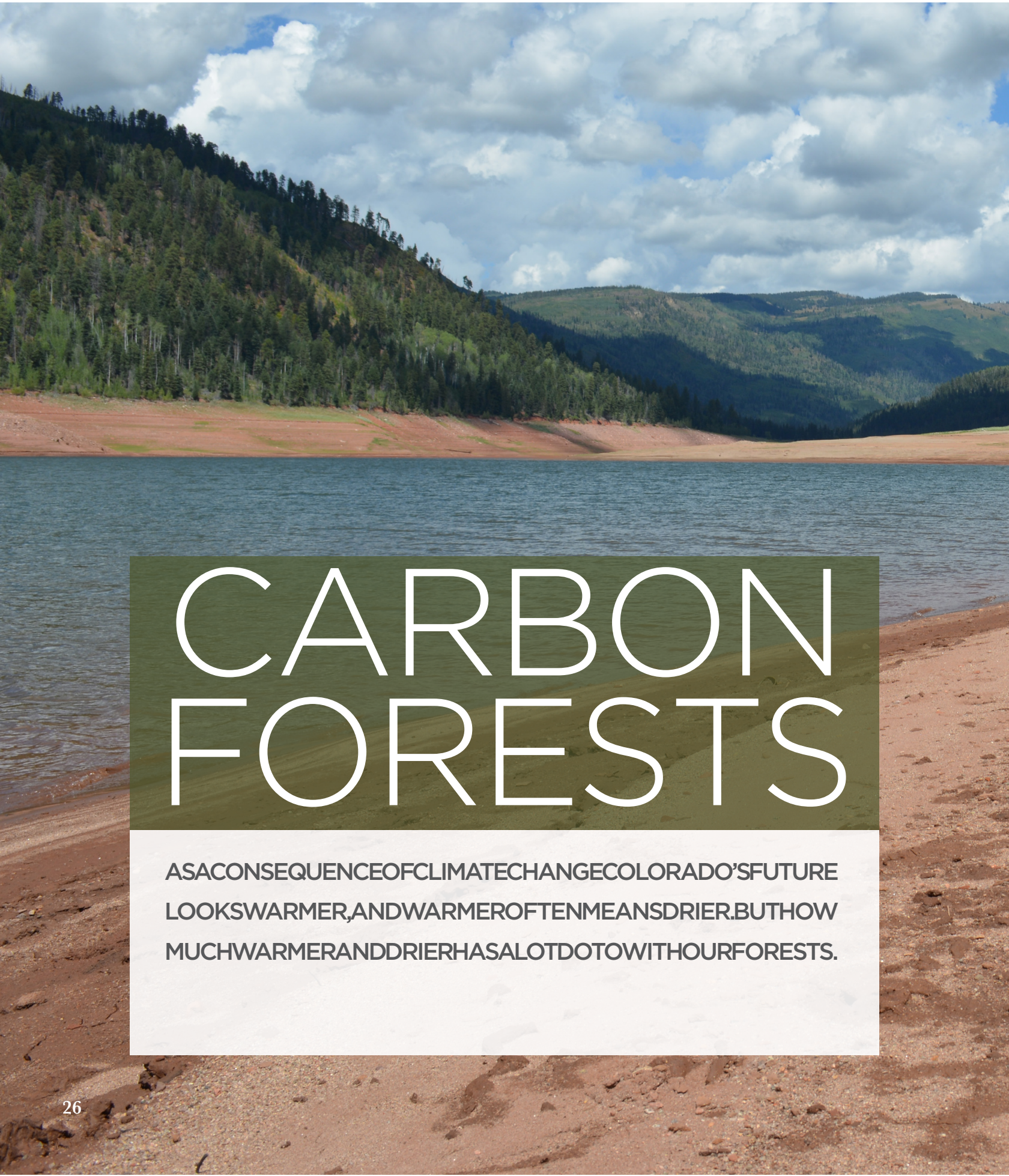
is hydrophobic and acts like a layer of heavy-duty black trash bags laid out on the forest floor, repelling water and increasing erosion.[9] During a fire, some parts of the forest may experience high severity burns while others experience low, so hydrophobic layers often occur as patchwork, covering only the most severely burned parts of the fire.

The complicated and critical connection between forests and watersheds is often reestablished at the first return of rains to a burn area. When rains finally return and pour over this hydrophobic layer, which is sometimes buried inches deep, they can send a flush of sediment and ash-ridden water into nearby creeks, streams and rivers, sometimes damaging homes or communities and inundating critical water infrastructure. Under ideal conditions, initial and subsequent precipitation may be in the form of snow, with winter freezing and thawing helping to break up hydrophobic layers.

Although post-fire flooding can feel like salt in an open wound for humans, floods in small doses can have important benefits for watersheds and surrounding forests. While the initial influx of sediments and organic matter into watersheds can heat rivers and kill fish and other aquatic life, over the long-term the distribution of nutrients and debris can create critical habitat for and improve river health in the case of small floods. Of course, many of the benefits and harm derived from a fire depend on how the fire burned. For example, a low-severity fire might deliver a small influx of sediment and debris into a stream, while a high-severity fire may release so much sediment into a watershed that it destroys habitat and suffocates aquatic life, degrades water quality and damages infrastructure.

After the Fire

Regeneration and recovery are the next steps for both forests and human communities, but they occur on very different timeframes. Communities impacted by a wildfire may take decades to recover - for homes to be rebuilt, infrastructure repaired, and economic losses stabilized. The same is true for forests, but the scale of change and time for recovery are much greater. And, given the impacts of climate change, forests are less likely than before to return to their pre-fire conditions. Wildfires may act as catalysts for dramatic landscape-scale changes species that are better acclimated to hotter and drier conditions ❊



CARBON FORESTS

AS A CONSEQUENCE OF CLIMATE CHANGE COLORADO'S FUTURE LOOKS WARMER, AND WARMER OFTEN MEANS DRIER. BUT HOW MUCH WARMER AND DRIER HAS A LOT DO TO WITH OUR FORESTS.

The 2018 drought has stressed human and natural systems in Colorado. Across the state, reservoirs like the one shown here are near all-time lows.

Throughout this year's forest report, we've delved into some of the connections between forests and water. In the preceding features, we've examined impacts of drought on forest, the impacts of climate change on drought, the importance of forests for human water supplies, and the intersection of drought, wildfire, and floods. In our investigations, we've found a future muddied by uncertainty and tangled with interconnections. Like a spider's web, it's impossible for any individual strand to change without impacting the entire system.

Climate and Forests 400 Million Years Ago

To truly understand the connections between forest and climate we need to go back 400 million years to a time when woody plants first began evolving. The earth was a very different place: it was considerably hotter and there was far more carbon in the atmosphere. As forests spread across the globe they absorbed massive amounts of carbon. While some of this carbon was released when plants died, much of it was buried, eventually becoming coal, oil, and natural gas. Over time trees stored enough carbon to help lower the temperature of the Earth making it habitable for humans and millions of other species.

Climate and Forests Today

Today, Earth's forests (including vegetation and soils) contain more carbon than the atmosphere. Each year healthy forests absorb carbon dioxide and help slow the rate of climate change. In some cases, higher atmospheric carbon increases the growth of forests (similar to an athlete from high elevation performing better at sea level). In many cases, it has no effect. Other nutrients such as water, phosphorus, nitrogen, or potassium limit a plants growth rather than carbon in the air.

In the western US, changes in available water are having more profound impacts than increased carbon in the air. Across the globe, climate change is causing temperatures to rise. Scientist estimate that about half of the area burned by wildfires in the western US between 1984-2015 can be attributed to worsening fire conditions caused by climate change.[10] The 2000-2012 mountain pine beetle outbreak in Colorado was much larger than any other recorded outbreak. The unprecedented extent of the outbreak is largely attributed to higher temperatures and lower precipitation. In some areas, the dramatic increases in tree mortality due to climate change mean that forests are adding more carbon to the atmosphere than they're absorbing.

The hot and dry conditions causing wildfires and beetle outbreaks cannot be written off as natural variability.

Looking specifically at drought between 2000 - 2014 in the western United States, scientist have learned several things. During this period, Colorado River flows were on average 19% below the 1906-1999 average. Scientists with the Colorado River Research Group found that 17-50% of the reduced flows resulted from higher than average temperatures (2.5°F over the past 50 years in Colorado).[11] Other research found that between 900-1,300 AD when temperatures in the Northern Hemisphere were 1.8 °F above normal, drought was more severe, occurred more often, and lasted longer.[12]

Climate change in Colorado could result in less available water for ecosystems and people.

An Uncertain Future

When we try to put everything together, it becomes dizzying. As the climate warms, forests die-off from drought and insects, and wildfire increases. When forests die they release more carbon, increasing the rate of climate change. Without forests to move water and trigger precipitation, some areas dry out even more, potentially causing additional forests to die-off. There isn't much good news in any of that. The best we can hope for is that forests are more resilient to climate change and the recent scale of die-off doesn't continue. All of this begs the question: what can be done?

If you're concerned about water and forests in the West, it's clear that climate change is one of the most pressing challenges. To even begin addressing climate change, rapid decarbonization is crucial. Individual action isn't enough. While taking the bus and changing light bulbs is important, we need societal action. Pressuring governments, corporations and utilities will be essential in mitigating climate change. That means voting with ballots and dollars for people and policies that support climate action. If we as stewards of our planet don't quickly bring down our carbon emissions to limit global warming, the consequences will be dramatic. But just limiting carbon emissions isn't enough anymore. As we've seen, the water cycle and forests in Colorado are already impacted by climate change and with the carbon emissions almost guaranteed to continue at some level for the immediate future, those impacts will only increase. In addition to reducing carbon emissions we need to adapt to the existing impacts of a warmer and drier West. ❊

> "...half of the area burned by wildfires in the western US between 1984-2015 can be attributed to worsening fire conditions caused by climate change."

RESULTS

Students participate in a forest health study on Reservoir Hill in the Pagosa Ranger District

MOUNTAINSTUDIESINSTITUTE-FORESTEDUCATION

AsthelocalproviderofscienceresearchandeducationMountainStudies Instituterecognizedauniqueandcriticalopportunityin2018toengagethe public around issues of watershed health.

The winter 2017/2018 snowpack saw near record lows and local anticipation of the impending fire season put communities in the San Juan watershed on edge. In order to address the complexity and breadth of the issues at hand, MSI held a three-part Forest and Fire Learning Series and invited expert speakers and panel presentations to cover forest health and ecology, smoke dynamics and effects, current drought conditions, available fire mitigation resources, management strategies, insect infestation, and the future conditions and management of our forests.

In addition to the events MSI hosted to address community concerns related to fire, the organization engaged community members through citizen science opportunities to observe and document beetle kill impacts on Molas Pass and, later in the summer of 2018, to monitor and evaluate the impacts of the 416 fire through post-burn assessments of aquatic life. We offered tours and lectures in the nearby Missionary Ridge burn scar, hosted a conversation on the relationship between conservation and recreation, conducted ongoing forest health monitoring (see "Four Mile on page 34), and developed a monitoring strategy for the 416 burn scar so we can better track and understand how local forests are regenerating after fires, and what that means for forests of the future. ❊

Participants during a tour of the West Fork Fire burn scar during the 2018 Briding the Divide event, organized by MSI.

416 FIRE, POST-BURN MONITORING

On June 1 of 2018 the 416 Fire was ignited in southwest Colorado, just 10 miles north Durango. Over the next six weeks, the fire burned 54,129 acres of prized San Juan National Forest lands in the Hermosa Creek drainage. No structures burned in the fire and no human lives were lost.

By many accounts, the 416 was a fire that helped to build future resilience in the watershed and perform critical ecological functions associated with fire.

But as we acknowledge in the "Forests, Flood and Fire" article, not all impacts of fire occur during a burn itself. While the flames of the 416 did not damage homes, storms that occurred in July and September caused significant flooding and damage from debris flows, creating concern in southwest Colorado communities about the potential impacts to water quality and aquatic life. In response to community concerns, MSI expanded our water quality monitoring efforts to collect samples from Hermosa Creek and the Animas River.

Beginning in mid-June, MSI collected samples during several precipitation events as well as during stable weather conditions. Here are some of the key findings form our early monitoring efforts:

- Water quality deteriorated in Hermosa Creek and the Animas River immediately following precipitation events that caused runoff from the 416-burn area.

- Following precipitation events, several water quality parameters - such as aluminum, iron, and mercury - temporarily reached levels of concern for aquatic life. Concentrations of suspended sediment could have been high enough to inhibit fish gill function and smother habitat of benthic macroinvertebrates.

- For the Animas River at Rotary Park, we can compare the post-fire levels of aluminum, iron, lead, and manganese to historical observations over the past couple of decades from MSI and the Colorado River Watch program. It is clear that during storm events following the 416 Fire, we documented extraordinarily high levels of aluminum, iron, and manganese in the Animas River at Rotary Park.

For the full report: mountainstudies.org/animasriver

COLLABORATNG FOR FOREST AND WATERSHED HEALTH

Multiple collaborative efforts in the San Juan Forest and watershed are working to promote effective cross-boundary forest management. These groups each have their own character and direction, but all bring together diverse voices (including industry, environmental NGO's, and resource managers) to inform and engage with public land management and work to expand community knowledge of and engagement with issues of forest and watershed health.

SAN JUAN HEADWATERS FOREST HEALTH PARTNERSHIP (SJHFHP)

For the past decade, the San Juan Headwaters Forest Health Partnership has provided a forum for stakeholders to share their perspectives and work together to develop science-based collaborative priorities for management and monitoring of forests in the Pagosa Ranger District of the San Juan National Forest. The group convenes monthly, supports ongoing monitoring efforts, and hosts regular outreach events. Further, the partnership works closely with teachers at Pagosa High School to offer students relevant opportunities to inform local forest health management. www.sanjuanheadwaters.org

DOLORES WATERSHED RESILIENT FOREST COLLABORATIVE (DWRF)

The Dolores Watershed Resilient Forest Collaborative is a network of local, regional, and national groups and agencies working in the upper Dolores River watershed. Participants in the collaborative share resources, identify cross-boundary management priorities, and work on projects to (1) promote forest health and resilience to disturbance across vegetation types, (2) reduce wildfire risk to lives, property, infrastructure, and water supplies, and (3) increase local timber industry capacity to complete cost-effective forest management treatments. www.dwrfcollaborative.org

TWO WATERSHEDS - THREE RIVERS - TWO STATES

COHESIVE STRATEGY PARTNERSHIP (2-3-2)

The 2-3-2 Cohesive Strategy Partnership (The 2-3-2) brings together partners from across a 5-million-acre geography in southwest Colorado and northern New Mexico to work together to protect and preserve forest health, water quality, wildlife, and communities within the San Juan, Chama and Rio Grande Watershed Landscapes. The group elevates the efforts of smaller, local collaboratives to support coordinated, landscape-scale planning and projects that emphasizes public and private partnerships, bridge geographic boundaries, and address agency management constraints to deliver integrated results that cannot be accomplished when working separately. www.232partnership.org

MONITORING FORESTS - FOUR MILE CASE STUDY

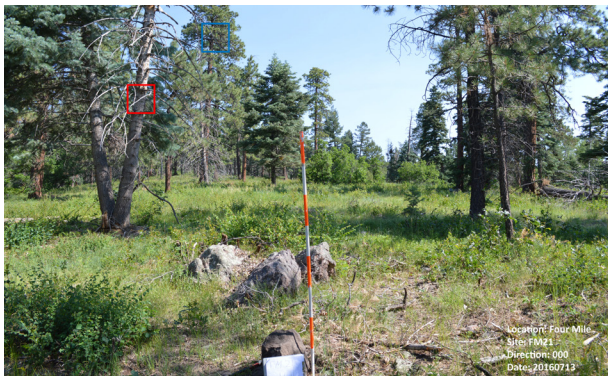
In the Pagosa Ranger District of southwest Colorado, the Dutton Ditch captures water from streams and creeks in the San Juan Mountains and feeds it to a series of both open channel and piped ditches that provide water for the town of Pagosa Springs. The Pagosa Area Water and Sanitation District manages the critical water infrastructure and determined that it was highly vulnerable to wildfire.

To address this vulnerability, they catalyzed a public-private partnership to develop a strategy for reducing and removing fuels in the area to minimize the risk of impacts from wildfire. Called "The Fourmile Fuels Reduction Project", the mitigation effort comprises 858 acres of warm-dry mixed conifer forest, dominated by ponderosa pine, with a dense understory dominated by Gambel's oak. Ten units in the project area were selected by the San Juan National Forest for mastication with the goal of reducing the understory density and, thereby, the potential impact of possible high severity fire. In order to gauge the effectiveness of their efforts, the San Juan National Forest contracted Mountain Studies Institute to assess the change in understory conditions and stand structure pre and post mastication. Pre-treatment monitoring occurred in August of 2015, mastication in the fall of 2015 and post treatment monitoring in July of 2016. MSI concluded that all units treated showed an average of a 69% reduction in shrub and understory composition post treatment. Pre and post photographs taken at each plot reflect the reductions in understory density and composition as well as the lack of change in overstory structure.

AUGUST 2015

Left: Pre mastication and thinning

AUGUST 2016



Right: Post treatment

Treatments that paired thinning and mastication proved successful and, more importantly, primed the site for future prescribed burn. In untreated areas, Gambel oak grows unchecked and builds up as a hazardous fuel. Mastication removes this vertical fuel hazard by spreading it on the forest floor. If a prescribed fire is planned for the area, it will move through and sweep up those small fuels and, if a wildfire moves through, the risk of a crown fire is reduced by the reduction in ladder fuels. Because forest management requires a long-term and continuous strategy, better understanding how these efforts work in concert with one another helps the Forest Service to plan more efficient and strategic treatments in the future. ❊

Things you can do to help your local forest.

Vote for candidates that prioritize your environment

Volunteer with organizations that support your local forest

Conserve water and energy

Get engaged with your local National Forest

Support Mountain Studies Institute

Photo: Pete McBride

WORKS CITED

1. Lukas, J., Barsugli, J., Doesken, N., Rangwala, I., & Wolter, K. (2014). Climate change in Colorado: a synthesis to support water resources management and adaptation. *University of Colorado, Boulder, Colorado.*

2. Colorado River Research Group (2018, March). When is Drought Not a Drought? Drought, Aridification, and the "New Normal".

3. 2016 Report on the Health of Colorado's Forests: Fire and Water. (2017, January). Colorado State University.

4. Mitton, J. B., & Ferrenberg, S. M. (2012). Mountain pine beetle develops an unprecedented summer generation in response to climate warming. The American Naturalist, 179(5), E163–E171.

5. Anderegg, W. R. L., Kane, J. M., & Anderegg, L. D. L. (2013). Consequences of widespread tree mortality triggered by drought and temperature stress. *Nature Climate Change*, 3(1), 30–36.

6. Brown, Thomas C., Hobbins, Michelle T., & Ramirez, Jorge A. (2008). Spatial Distribution of Water Supply in the Coterminous United States. *Journal of the American Water Resources Association.*

7. US Department of the Interior, Bureau of Reclamation (2012). Colorado River Basin Water Supply and Demand Study. *Reclamation: Managing Water in the West*, 3-4.

8. Riley, Karin L & Loehman, Rachel A. (2016). Mid-21st Century climate changes increase predicted fire occurrence and fire season length, Northern Rocky Mountains, United States. *Ecosphere, an ESA open access journal.*

9. Brooks, Randy. After the Fires: Hydrophobic Soils. *UI Extension Forestry Information Series.*

10. Abatzoglou, J. T., & Williams, A. P. (2016). Impact of anthropogenic climate change on wildfire across western US forests. *Proceedings of the National Academy of Sciences*, 113(42), 11770–11775.

11. Udall Bradley, & Overpeck Jonathan. (2017). The twenty first century Colorado River hot drought and implications for the future. *Water Resources Research*, 53(3), 2404–2418.

12. Woodhouse, C. A., Meko, D. M., MacDonald, G. M., Stahle, D. W., & Cook, E. R. (2010). A 1,200-year perspective of 21st century drought in southwestern North America. *Proceedings of the National Academy of Sciences*, 107(50), 21283–21288.

13. Westerling, Anthony LeRoy. (2016). Increasing Western US Forest Wildfire Activity: Sensitivity to Changes in the Timing of Spring. Phil. Trans. R. Soc. B 371(1696): 20150178.

Mountain Studies Institute

SAN JUAN MOUNTAINS COLORADO

SCIENCE YOU CAN USE

mountainstudies.org | Printed on post-consumer material