

CHANGING WEATHER AND LIVELIHOODS IN RURAL COLORADO

A report on 21st century impacts and
adaptation in the farming, ranching, and
outdoor recreation sectors

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Acknowledgements

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Executive Summary

Introduction

This report attempts to provide members of the policy-making and land management community with an introductory understanding of the broad array of issues facing rural and mountain communities in Colorado due to extreme weather events and changes in historical weather patterns. In addition, it aims to introduce the wide array of conversations - and strategies for action - currently being undertaken with the aim of adapting to these challenges. It is based, in large part, upon on-the-ground observations made by people living and working in rural and mountain communities of the state. Sources for these observations include conversations held in 2018 with actors in the ranching, farming, and recreation sectors, as well as local news coverage, government and non-profit sector reports, and the academic literature.

Key Messages

Rural communities are a critical part of Colorado's economy and way of life

Depending on the definition used, rural communities are home to between 500,000 and a million people in Colorado as of 2018. Though these communities are diverse in character, style of life, environmental situation, and economics, they are all characterized by some degree (often great) of connectedness with and dependency upon the iconic natural environments for which Colorado is well known. Industries related to farming and ranching have long been a part of many rural areas - as well as the state as a whole - and continue to play a central role in all areas of the state. In rural communities found on the Western Slope, and in the state's high-elevation mountainous areas, outdoor recreation and tourism - be it in the form of skiing, rafting, hunting, fishing, hiking, climbing, or otherwise - are also a critical and growing part of both local and statewide economic activity.

Rural communities are vulnerable to weather-related disasters and long-term change

As weather patterns and the occurrence of extreme weather have shifted over the last few decades, connections to natural resources and environments - as well as the character of rural communities themselves - have meant that the impacts to rural lives and livelihoods have been particularly acute. Due to diminished response and recovery resources, many small rural communities face difficulties in dealing with wildfires, floods, and other extreme events. Due to heavy dependence upon agriculture and outdoor landscapes, drought effects both rural economic well-being and the viability of rural communities as a whole. In mountain towns, where tourism often plays a prominent role, resources to adapt may be more readily available. However, even well-resourced rural areas face significant risks and future challenges should long-term drought, temperature rises, and increased extreme event occurrence continue as they have since the turn of the century. In many cases, the intensity of these risks go well beyond those faced by large cities.

Adaptation to challenging environmental conditions is a part of rural life, but significant barriers exist for those hoping to address current and future challenges.

Livelihoods that depend upon the land have long required those who practice them to pay careful attention to weather and other environmental conditions, and to respond in prudent ways. In Colorado, numerous efforts are already underway to help farmers, ranchers, and recreational businesses of all sorts find ways to deal with the “new normal” of 21st century weather patterns and variability. These include practices within businesses - such as changing farm practices - as well as community- and regional-scale coordination to support rural industries and more effectively manage shared resources during times of stress. However, many rural communities face significant challenges when it comes to addressing weather-related risks. These include a lack of economic resources for program implementation, a lack of coordination at the local level around critical risk management issues, and pressures related to demographic and socio-economic factors that make implementing new strategies and shouldering the risks of innovation untenable. At the same time, statewide scarcity of water, rising prices for farmland, and increased population pressure on previously “isolated” mountain communities may place limits on adaptation options.

Policies and programs aimed at improving the well-being of rural communities must be rooted in local values and ways of thinking

Colorado’s rural communities are highly diverse in terms of how they engage with global and national issues, including climate change. As a result, those hoping to find ways to build resilience and improve adaptation in vulnerable sectors like agriculture and outdoor tourism must find ways to work within existing, trusted systems for understanding science, land management best practices, and long-term weather patterns - be they national weather programs, Agricultural Extension services, county commissioners’ offices, or regional business alliances. At the same time, Colorado’s academic and scientific communities must find ways to become more engaged, at the ground level, with the needs of rural communities, both in the form of more practical research and development programs and in terms of bringing up-to-date information and science to trusted institutions within rural communities. Similarly, while national-level risk management programs (e.g., crop insurance) play a significant role in supporting rural communities during times of weather-related stress, the rapidly changing character of the farming, ranching, and recreational sectors mean that programs must be able to evolve to meet on-the-ground needs and new business configurations.

For while the risks that Colorado’s rural communities face are real, and are already having severe impacts in many areas, adaptation has always been a part of rural life, and will likely continue to be so as global scale changes are felt at the local scale. However, adaptation is neither easy nor cheap, and if changes occur too rapidly or with too great of an intensity, even the most resilient community may face no option but to abandon the ways of life that have defined this state for over a century. If policy-makers, planners, and resource managers aim to avoid this outcome, then a dynamic approach to learning about, engaging with, and supporting rural community well-being will be required.

Introduction

Significant work is underway across the United States to better understand how changes in the global climate are shaping impacts at the national and regional scale.¹ However, whether one is planning national policy, regional land management, urban water infrastructure, or simply next year's crop, long-term climate information and regional weather trends are not enough to ensure adaptive and efficient decision-making. Much as with politics, all adaptation is *local*, as it is local communities that experience weather, perceive it, react to it, and try to make a living within its narrow range of mercy. To achieve goals of reduced vulnerability and improved resilience in rural communities, decision-makers - of whatever sort - need to understand how the systems they are tasked with supporting operate on the ground, and how local people, living with day to day weather conditions, are impacted by and respond to the challenges their environments present. Few places make this principle more obvious than Colorado, whose diverse terrain, climate, local communities, and ways of life make generalization a risky endeavor, at best. Here, where if you do not like the weather, you need merely wait - and if you don't like the people, you just have to drive to the next town - local perspectives are a critical source of information on how changes in global climate are impacting everyday life. and, more importantly, how we might take steps to adapt to the challenges caused by these impacts. This is especially true in the state's many rural communities, where livelihoods and ways of life are often tied closely to the surrounding lands, livestock, wildlife, pastures, and forests - all of which are already responding dramatically to increased temperatures and more variable precipitation.

This report aims to collect insights into just these local-scale interactions between people and weather, with a specific focus on rural communities. In contrast with other assessments that examine statewide climate trends or specific threats to resources using official, scientific resources,² this document aims to gather together stories from the people across Colorado whose daily work brings them into close contact with the local-level consequences of the state's changing weather. It hopes to shed light on how rural communities across the state - whose economies are linked to local weather dynamics in intense and complicated ways - are being affected by and

Our Approach:

This report differs significantly from most work on weather-driven risks, both in the focus of its analysis and the resources used in the process. In it, we attempt to utilize the experiences of practitioners of various land-based livelihoods - that is, ranching, farming, and various outdoor recreation-related businesses - to shed light on how changes in weather patterns across the state are affecting the rural economies and communities in which they play an important role. To do this, we rely upon a variety of sources, including telephone conversations with rural residents and organization representatives, news stories related to weather related impacts, the scientific literature, reports from various trade organizations and conservation groups, and a number of drought impact reporting and general resource management tools that integrate local-scale information. As a result, it is not meant to be either comprehensive in scope nor definitive in its descriptions. Instead, it is meant as but an introduction to the variety of complex challenges - and opportunities for adaptation - presented by changing weather in the 21st century to rural Colorado communities, both for those in the decision-making community whose experience with rural Colorado life is limited, and for those living in rural Colorado who hope to learn from the experiences of others across the state.

responding to both changes in weather and the natural resource impacts those changes cause.

In this, our primary goal is to provide decision-makers at the state and national levels with better information on how to ensure that policies serve to enable effective adaptation to mounting weather variability and extremes. At the same time, however, we also hope to demonstrate how global climate change, experienced on the ground as storms, drought, hail, wildfire, and other tangible weather-driven events, is already shaping the ways in which Colorado communities live, work, play, and manage their businesses. Because of this, this report also hopes to demonstrate just some of the numerous ways in which people across the state are already working to adapt to increasingly unreliable weather. Ranging from farm- and ranch-level strategies for resource management to grass-roots regional water conservation and watershed restoration efforts, Coloradans - urban and rural alike - are already demonstrating significant capacity for innovation and adaptive thinking as the state's weather changes, much as they long have in the face of the state's already tumultuous climate.

That said, significant hurdles - some, owing the nature of weather impacts themselves, and others, to policy and resources - stand in the way of even the most ingenious and innovative communities. Although many are already making strides through the modification of long-established adaptation strategies in attempts to deal with drought, wildfire, or other readily observable weather phenomena, it is increasingly clear that new strategies and solutions will be required as changes in weather increase. Because of this, we also examine some of the practical, scientific, and policy approaches currently being discussed in Colorado communities, bearing in mind while doing so that, in a state as diverse as Colorado, no one solution - or even set of solutions - will likely be the answer to all problems.

The report is structured as follows: first, a general overview of the ways in which Colorado weather has changed over the last few decades and how it is expected to continue to change in the future. Next, we detail examples of how these changes are impacting rural communities and livelihoods across the state, both in terms of economic impacts as well as less tangible - but no less important - damage to deeply-rooted ways of life. We then turn to on-going examples of adaptation from across the state, and, finally, some of the solutions currently being proposed, both to specific adaptation challenges and broader barriers to building resilience.

References

¹ See, for example, the 2017 and 2018 U.S. Global Change Research Program Reports:

Wuebbles, D.J., D.W. Fahey, K.A. Hibbard, B. DeAngelo, S. Doherty, K. Hayhoe, R. Horton, J.P. Kossin, P.C. Taylor, A.M. Waple, and C.P. Weaver, 2017: Executive summary. In: Climate Science Special Report: Fourth National Climate Assessment, Volume I [Wuebbles, D.J., D.W. Fahey, K.A. Hibbard, D.J. Dokken, B.C. Stewart, and T.K. Maycock (eds.)]. U.S. Global Change Research Program, Washington, DC, USA, pp. 12-34, doi: [10.7930/J0DJ5CTG](https://doi.org/10.7930/J0DJ5CTG).

USGCRP, 2018: Impacts, Risks, and Adaptation in the United States: Fourth National Climate Assessment, Volume II [Reidmiller, D.R., C.W. Avery, D.R. Easterling, K.E. Kunkel, K.L.M. Lewis, T.K. Maycock, and B.C.

Stewart (eds.]. U.S. Global Change Research Program, Washington, DC, USA. doi:10.7930/NCA4.2018.
Recovered at: <https://nca2018.globalchange.gov/downloads/>

² Several reports on extreme weather, long-term climate change, and the vulnerability of Colorado communities and resources have been compiled in the last decade. For more information, see:

Colorado Natural Heritage Program. "Climate Change Vulnerability Assessment for Colorado Bureau of Land Management." Fort Collins, CO: Colorado Natural Heritage Program, Colorado State University, 2015.

Gordon, Eric, Ojima, Dennis, Childress, Amber, Jedd, Theresa, Klein, Roberta, Lukas, Jeff, and McKeown, Rebecca. "Colorado Climate Change Vulnerability Study: A Report by the University of Colorado Boulder and Colorado State University to the Colorado Energy Office." University of Colorado Boulder and Colorado State University, July 2014.

Lukas, Jeff, Barsugli, Joseph, Doesken, Nolan, Rangwala, Imtiaz, and Wolter, Klaus. "Climate Change in Colorado: A Synthesis to Support Water Resources Management and Adaptation - Second Edition." University of Colorado Boulder, August 2014.

McNeeley, Shannon, Corrie Knapp, Trevor Even, John Gioia, and Julia Nave. "Colorado Bureau of Land Management Social Vulnerability Assessment." Fort Collins, CO: North Central Climate Science Center, 2017.

Changing Weather in Colorado

If someone were to ask ten native Coloradoans what the weather was like in their state, they might find themselves confused to hear a wide range of answers, no two of which seemed to describe exactly the same place. This would be no accident: with its towering Rocky Mountain peaks cutting through much of the state's center, its wide, sloping canyons along the western slope, and its broad grassland plains in the east, describing the "climate" in Colorado is an exercise in frustration - or at least, exhaustion - as its often chaotic terrain and position at the center of the North American continental landmass mean that its local weather patterns are defined by both high levels of diversity from one area to the next and wild levels of variability from day-to-day and year-to-year. Dependent upon innately variable atmospheric rivers of ocean moisture flowing down from the arctic and north-western Pacific coast, and north from the Gulf of Mexico, the lion's share of the precipitation in the state comes as the result of high altitude condensation, as water vapor suspended in the atmosphere is pushed upwards by the rapidly sloping terrain. As a result of this phenomenon, while the state's lower elevation regions may only receive between 10-15 inches of total precipitation per year, along the sides of peaks and in the highland valleys of the Rocky Mountains snow and rain can add up to nearly four times as much, with some peaks along the Jackson/Routt county line in northwestern Colorado seeing upwards of 60 inches per year. In stark contrast, some areas, such as the San Luis and lower Grand Valleys see on average fewer than 10 inches, while others, such as the lower Arkansas Valley in southeast Colorado, see much of the (relatively abundant) moisture they receive lost to high winds and heat in the form of evaporation. As a result of this unequal distribution of water, the relationship between the people of the state, the weather they experience in the places they live, and the weather that ultimately determines the water resources they rely upon is not always direct, as it is heavily controlled by the state's vast network of creeks, streams, rivers, ponds, lakes, and, perhaps most importantly, man-made water diversions. Because of these networks, water that falls and freezes on the mountainside is able to eventually make its way to the much drier areas downstream, enabling settlement, industry, agriculture, and a wide range of outdoor recreational activities. What this also means is that, no matter where you live in Colorado, local weather conditions and those in the (often distant) mountains upstream both work to shape how you experience daily life, and how - in many rural areas - you go about seeking your livelihood.

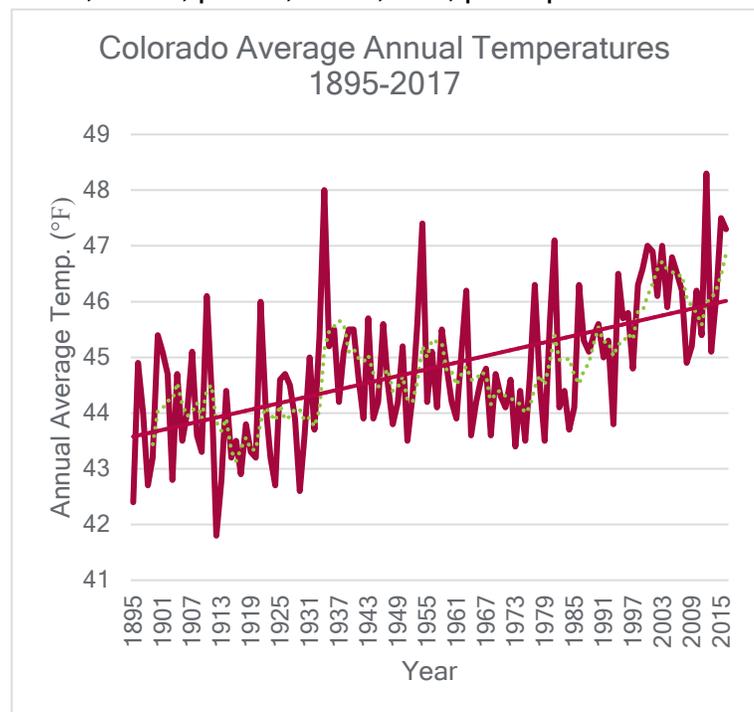


Figure 1 - Temperatures are rising across the state. Source: NOAA

Percent of State in Drought - 2000-2018

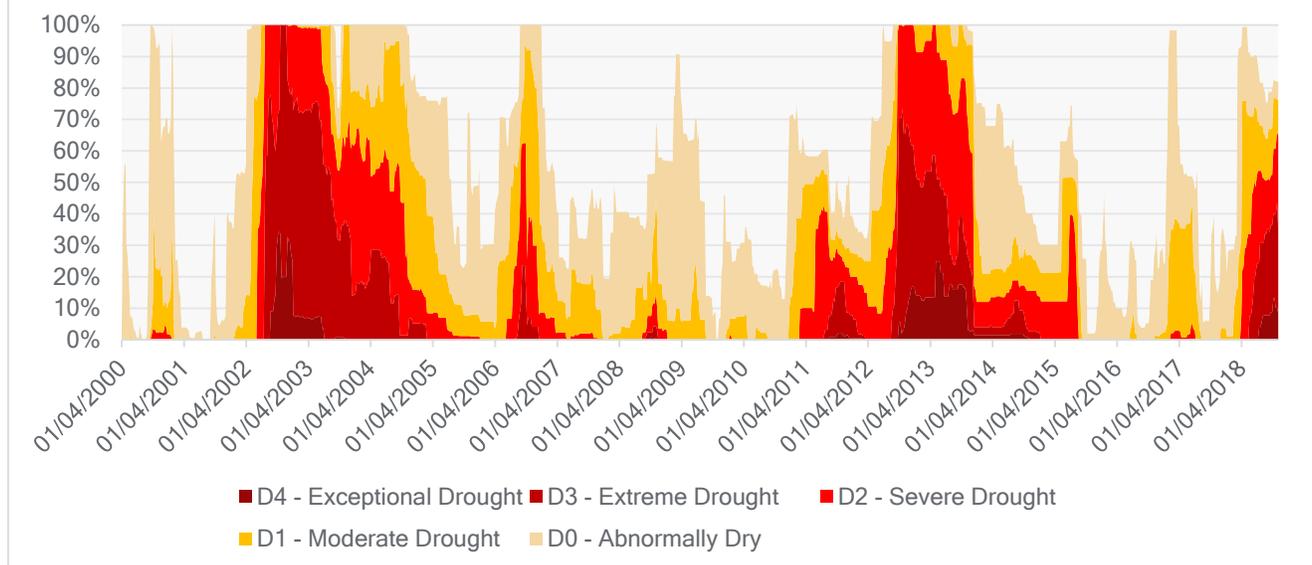


Figure 2 - Drought has been a mainstay of Colorado's statewide weather patterns over the last two decades.
Source: U.S. Drought Monitor

And while this has meant, for most of the state's history, that people in all walks of life have had to learn to deal with unpredictable and dangerous weather, recent decades have brought increasingly challenging conditions to many areas. Indeed, as another summer of extreme high temperatures, destructive wildfires, and costly drought conditions draws to a close, it seems more and more evident that the historically challenging weather patterns normally seen across Colorado are becoming even more intense. In this, the most consistent and readily observable trend has come in the form of higher temperatures, with the state as a whole having shifted over 2.0 degrees Fahrenheit above the 1900s average, with spring temperatures rising over 3.0 degrees over the same period.¹ As a result of these climbing temperatures (and the state's already fickle precipitation), drought conditions - or abnormally dry conditions caused by either low rates of precipitation and/or extreme rates of evaporation due to heat - have been at the center of much of the shift in how Coloradoans experience weather. Although no stranger to drought during the 20th century, with the 1934, 1954, and 1977 droughts standing out for their extraordinarily low precipitation², in just the 18 years since 2000 alone, Coloradoans have dealt with numerous extreme drought periods, with the most hard-hitting impacts happening outside of cities. These include the multi-year 2002-2006 drought (whose economic costs surpassed \$1.6 billion statewide), the 2007 and 2012 "flash" droughts, and now, in 2018, another year where almost one hundred percent of the state found itself facing some degree of abnormally dry conditions. In the southern portions of the state (as is often the case), the result is people and environments dealing with plummeting reservoir levels, parched soils, elevated wildfire risk, and withered pastures. Much like other extreme drought years in the past, the 2018 drought was preceded by a general failure of the expected wintertime snowfalls in both the mountains and plains followed by an early snowmelt, resulting in rivers running dry far earlier than expected in many regions. When these conditions combine with statewide trends over the last several decades toward higher temperatures that drive faster evaporation from soil and plants, the result is that extreme

drought states are becoming more common. Indeed, many areas could be described as having experienced a full decade or more of long-term drought conditions, prompting questions about just how dry the new “normal” for some parts of Colorado is going to be. ³

With these rising temperatures, while much of the change Colorado has seen over the last few decades has come in the form of water shortages - particularly during times when it is needed most - annual precipitation trends overall have remained more or less within historical ranges⁴. In Colorado, however, this means that the character, intensity, and magnitude of individual rain or snow storms has continued to present serious risks to Colorado communities, large and small. The 2013 floods that followed from intense rainstorms along the northern Front Range brought far-reaching impacts, with damage to property and infrastructure stretching from communities in the forested mountains to farming and oil and gas infrastructure on the northern Eastern Slope.⁵ Alongside these sort of large, extreme events, numerous smaller-scale flooding episodes have come about from localized but intense rainstorms. Similarly, in small headwaters and ski towns, earlier and more rapid snowmelt has meant more intense peak flows over shorter periods of time, often pushing river management infrastructure to its limits. Hailstorms, similarly, have shown new characteristics, with several “plowable” hail events (which result in large accumulations of hail, requiring road plowing) having been observed since 2000⁶. At the same time, watersheds across the state, often parched due to drought, have shown evidence of becoming less able to absorb moisture when rain finally falls, ultimately resulting in more intense surges of water moving through rivers and streams. When high altitude storms occur in areas recently burned by wildfire, in particular, runoff rates and the corruption of streams by debris and ash have created increasing concerns about water quality and treatment in many areas (e.g., Writer et al. 2014).

Wildfires, for their part, have also been showing signs of shifting to a new, more dangerous “normal,”

Quotes from the 2018 Drought

From the CoCoRaHS Drought Impact reporter, found at droughtreport.unl.edu

“While there have been some scattered rain showers around the San Luis Valley, there has not been enough to make a difference. The drought is persisting. Pastures are becoming short, cattlemen are in quiet desperation looking for pasture and hay that is affordable. The heat has crops well ahead of normal by anywhere from 2-3 weeks. Surface irrigation ended last month for all but the most senior water rights and without any subsurface moisture that is not going very far. Full fire restrictions are in place throughout the SLV on both public and private lands. Tourists are having to restrict their recreational activities. Warm water is affecting the fish, and wildlife is moving to water from the public lands.” – Rio Grande County, 07/9/2018

“One fruit tree is dying, vegetable garden is mostly dead, because Grand Junction (nearest station to us) has had <14% of normal rain so far this summer. We irrigate from water collected off our roof (mostly as melted snow in winter) and since the winter had hardly any snow, we have now run out of water. Native plants are doing poorly as well.” – Mesa County, 07/19/2018

“Native grasses haven't broken winter dormancy. Pasture has zero growth for 2018 grazing season. Ranchers feeding cattle. Herds being liquidated or put into feedlots.” – Otero County, 07/6/2018

"Very dry in Bent County and the western part of Kiowa County, already starting to cull cows, other people are talking about sending cows and calves to feedlot or early weaning calves and sending both to feedlots separately. The irrigation canals are saying 5 more runs of water in storage, water is not going across the fields and lots of fields are being fallowed or prevent planted. It looks like the dead of winter if it wasn't for the bar ditches being green. The rains have been very spotty and the high heat and winds have killed what moisture has come." – Ben County, 06/28/2018

"The wind has been horrible, very hot and dry, irrigation water is not going across the field like it should and people are taking cattle to the sale barn. Reports of people early weaning calves, and sending cows to the feedlot and out of state have also been reported" – Lamar, Prowers County, 07/10/2018

"Still very dry. We've been teased by rain in the distance, but no moisture here. Not even wildflowers are growing here this year. Disappointment Creek is noticeably lower than even a week ago. No green. The ground is very parched ... or as a visitor yesterday put it, "naked." The water truck is still watering the gravel while everybody else wonders how they're going to continue hauling water to cattle. BLM is watching the drought closely on behalf of the Spring Creek Basin Herd Management Area mustangs, ready to haul water when needed, which will be soon." – Redvale, San Miguel County, 05/22/2018

with fires burning with greater frequency, broader scope, and higher intensity than in the past across much of the state. Although a natural part of the long-term lifecycle of most of the state's varied landscapes, a century of fire suppression, growing development in areas with heavy vegetation, fire-prone invasive species, and more intense drought episodes have all combined to create fire impacts far beyond the historical norm. In fact, of the roughly 2.5 million acres burned in Colorado between 1980 and 2016, nearly 2 million did so after the year 2000, including a growing number of extremely large, multi-week fires, with many individual fires growing to tens of thousands of acres⁷. In addition to their effects on water and erosion, these fires have also changed the quality of our air, with low air quality an increasingly serious problem across much of the front range as smoke from fires mixes with pollution from local transportation and industrial activity.⁸ In 2018, many areas across the front range and beyond experienced severely impaired air quality due to both nearby fires and those burning across much of the northwestern portion of the North American continent.⁹

In short, the historically fickle weather patterns found across the state are changing. In most cases, they are becoming more extreme, more unpredictable, and more punishing to those who fail to heed their risks. As global trends toward higher temperatures and more unpredictable precipitation patterns continue, Colorado will likely face even more challenges from changing weather in the future, particularly in places where water is already scarce, landscapes are vulnerable to fire, and demand for both is growing. In rural areas, in particular, the stakes are high, as these areas are often both short on the infrastructure needed to deal with issues like floods, fire, and drought and long on the number of ways in which tempestuous weather can damage livelihoods and ways of life. In the following chapters, ask: if the weather in Colorado is changing, how is it affecting the state's numerous, diverse rural communities? And more importantly: what are those communities doing to deal with the challenges they face?

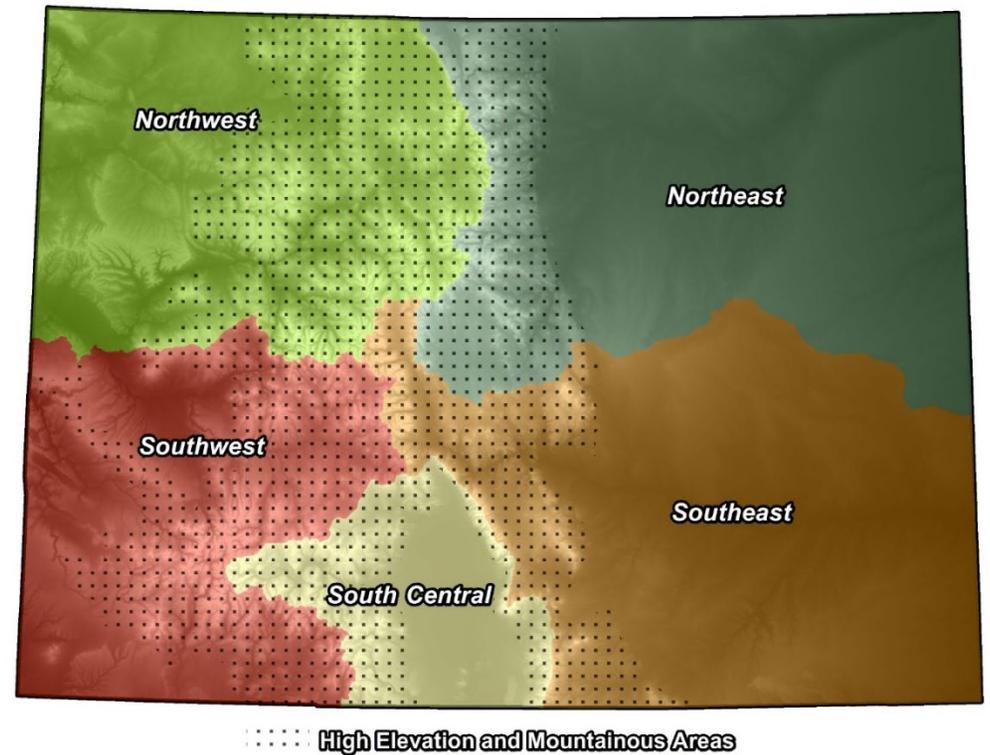
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- ¹ Lukas, Jeff, Barsugli, Joseph, Doesken, Nolan, Rangwala, Imtiaz, and Wolter, Klaus. "Climate Change in Colorado: A Synthesis to Support Water Resources Management and Adaptation - Second Edition." University of Colorado Boulder, August 2014.
- ² Ryan, W., Doesken, N., & Center, C. C. (2013). Drought of 2012 in Colorado. *Colorado Climate Center*.
- ³ See Lukas et al. 2014, also:
Lukas, Jeff, Barsugli, Joseph, Doesken, Nolan, Rangwala, Imtiaz, and Wolter, Klaus. "Climate Change in Colorado: A Synthesis to Support Water Resources Management and Adaptation - Second Edition." University of Colorado Boulder, August 2014.
- ⁴ Lukas et al. 2014.
- ⁵ Gochis, David, Russ Schumacher, Katja Friedrich, Nolan Doesken, Matt Kelsch, Juanzhen Sun, Kyoko Ikeda, et al. "The Great Colorado Flood of September 2013." *Bulletin of the American Meteorological Society* 96, no. 9 (September 2015): 1461-87. <https://doi.org/10.1175/BAMS-D-13-00241.1>.
- ⁶ Kalina, Evan A., Katja Friedrich, Brian C. Motta, Wiebke Deierling, Geoffrey T. Stano, and Nezette N. Rydell. "Colorado Plowable Hailstorms: Synoptic Weather, Radar, and Lightning Characteristics." *Weather and Forecasting* 31, no. 2 (April 2016): 663-93. <https://doi.org/10.1175/WAF-D-15-0037.1>.
- ⁷ *GeoMAC Wildfire Application*. (2018). *Geomac.gov*. Retrieved 30 November 2018, from <https://www.geomac.gov/>
- ⁸ Alman, B.L., Pfister, G., Hao, H., Stowell, J., Hu, X., Liu, Y. and Strickland, M.J., 2016. The association of wildfire smoke with respiratory and cardiovascular emergency department visits in Colorado in 2012: a case crossover study. *Environmental Health*, 15(1), p.64.
Hallar, A Gannet, Noah P Molotch, Jenny L Hand, Ben Livneh, Ian B McCubbin, Ross Petersen, Joseph Michalsky, Douglas Lowenthal, and Kenneth E Kunkel. "Impacts of Increasing Aridity and Wildfires on Aerosol Loading in the Intermountain Western US." *Environmental Research Letters* 12, no. 1 (January 1, 2017): 014006. <https://doi.org/10.1088/1748-9326/aa510a>.
- ⁹ Skilling, Chaney. 2018. The Denver Post. *Colorado wildfire smoke creates unhealthy air quality conditions statewide*. [online] Available at: <https://www.denverpost.com/2018/07/06/colorado-wildfire-air-quality/> [Accessed 30 Nov. 2018].

Where (and *who*) is “Rural” Colorado?

Numerous definitions exist for what “rural” means, ranging from the simple to the complex. In the former case, rural areas are simply those with low population overall and low population density, i.e., the number of people per square mile. In the latter case, rural areas are defined by both low population density and limited access to modern services, such as hospitals, law enforcement, fire protection, water provision, and universities. In Colorado, however, access to cities alone does not a city dweller make, as numerous areas with deep connections to rural livelihoods find themselves increasingly close to rapidly growing urban centers. As a result, we expand our definition of rural to include those areas where land-based livelihoods - such as ranching, farming, and outdoor recreation - are seen as an important means of economic activity by local residents. In addition, we also include those who, while potentially living in cities, rely upon natural landscapes and ecosystems for their livelihood and culture, such as hunting guides, recreational outfitters, river rafting companies, and fishing guides.

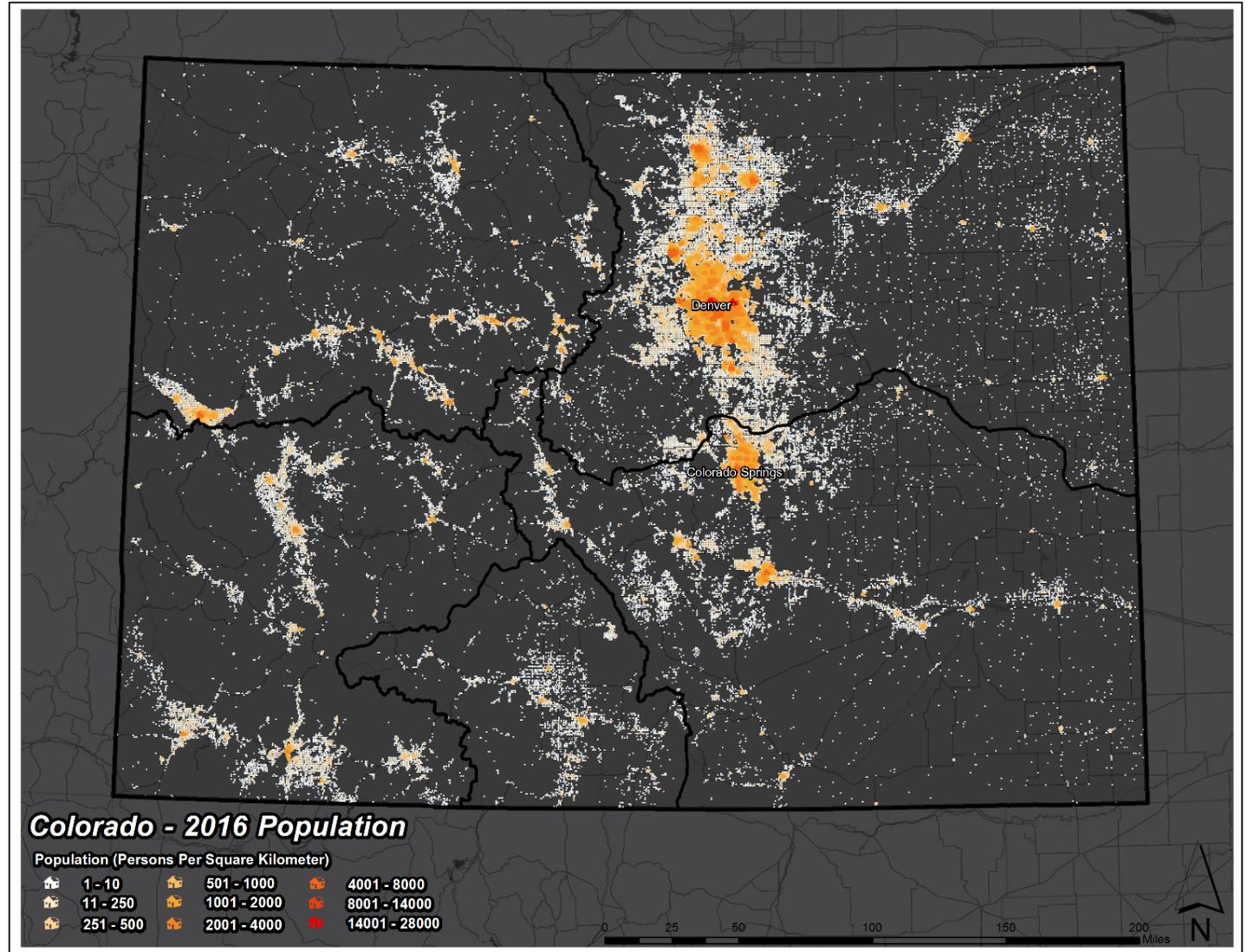
Because of Colorado’s diverse environmental contexts, not all rural communities face the same set of challenges, nor do they experience common challenges - like drought - in exactly the same ways. For the purposes of this project, we divide the state into five areas that correspond roughly to major environmental, social, and long-term weather patterns, and that thereby help to distinguish between the specific circumstances of rural communities across the state. These are, in no particular order: 1) Northeastern Colorado, which includes the Front Range cities in and north of the Denver metro area, as well as Greeley, Sterling, and other medium and small towns in the South Platte and Republican River basins; 2) Southeast Colorado, which includes the Arkansas and Purgatoire River basins, the large cities of Colorado Springs and Pueblo, and the numerous rural communities located in the eastern plains; 3) South Central Colorado, including the San Luis Valley and the surrounding mountains; 4) Southwest Colorado, including the headwaters of the San Juan, Dolores, and Gunnison rivers; and 5) Northwest Colorado, which contains the Yampa, White, and Upper Colorado rivers, as well as the largest concentration



Map 1 - Regions referred to in this report.

of people in Colorado outside of the Front Range, in cities around and upstream from Grand Junction. In each of these areas, we also distinguish between the lowland areas (here, areas below 7000 ft. in elevation) and the highland, mountainous areas (areas 7000 ft. and above), as weather and ecosystem hazards are highly influenced by elevation and local topographic complexity.

In the following pages, we provide several maps that attempt to illustrate how people and their communities are distributed across each region, and how they fit into different classifications of “rural.” We also provide several maps that illustrate what it means to live in these different areas, both in terms of local weather patterns and the overall nature of the local environment.



Map 2 - Population data from LANDSCAN, a high resolution dataset that models human habitation at the square kilometer scale. Lighter colors represent areas of habitation with low population density, i.e., areas likely to be seen as “rural.”

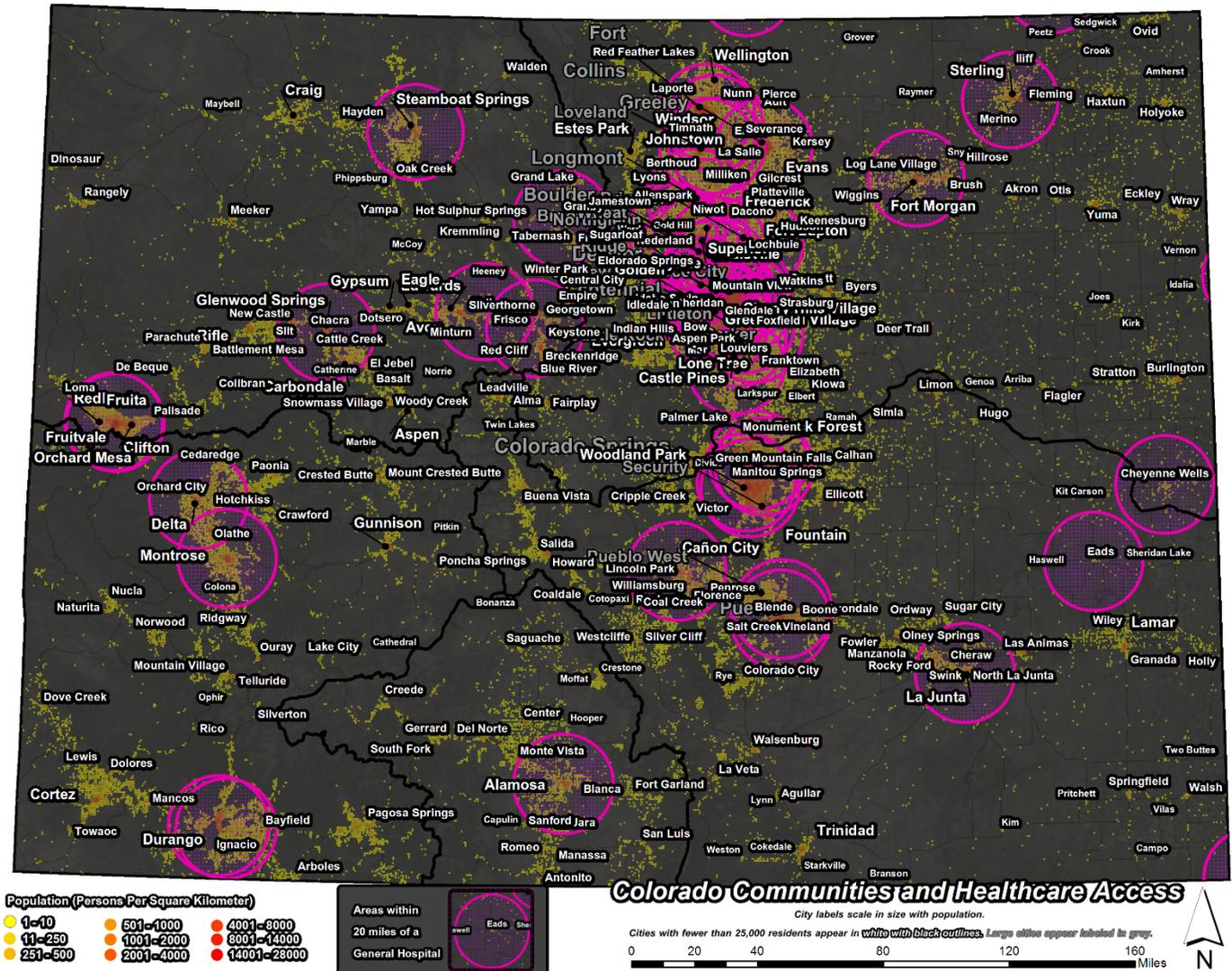
Population

The state’s population is far from evenly distributed, and owes much to where settlers in the late 1800s found ready access to water and natural resources. Today, roughly 80% of the state’s population is concentrated along the northern-central Front Range, which runs roughly from Fort Collins in

the north to Pueblo in the South, including the large and rapidly growing cities of Denver, Boulder, Aurora, Longmont, Greeley, Colorado Springs, and Castle Rock. The rest of the state, however, shows a highly dispersed pattern of settlements. In the western half of the state, communities are largely confined to the small valleys and parks found between the many peaks and canyon walls of the southern Rocky Mountains. In the east, vast grasslands - now given over to irrigated and dryland agriculture, are home to numerous small towns and isolated homesteads, some of which have been within the same family for over a century.

Services

Rural communities in Colorado are often faced with a lack of local services, such as general hospitals capable of conducting complex procedures. Similarly, fire-fighting, law enforcement, and emergency management capacities may be minimal or, in the case of major disaster events, insufficient. In many areas, access to the internet - and in some cases, cell phone service - is highly limited. Infrastructure in these areas, unlike in cities, is also often a highly individualized affair, with ranches, farms, and isolated resort communities managing



Map 3 - Access to healthcare is often a serious challenge in many of Colorado's rural communities. When serious accidents occur, help may be hours away, and special medical procedures may require evacuation by air to Denver or other large cities.

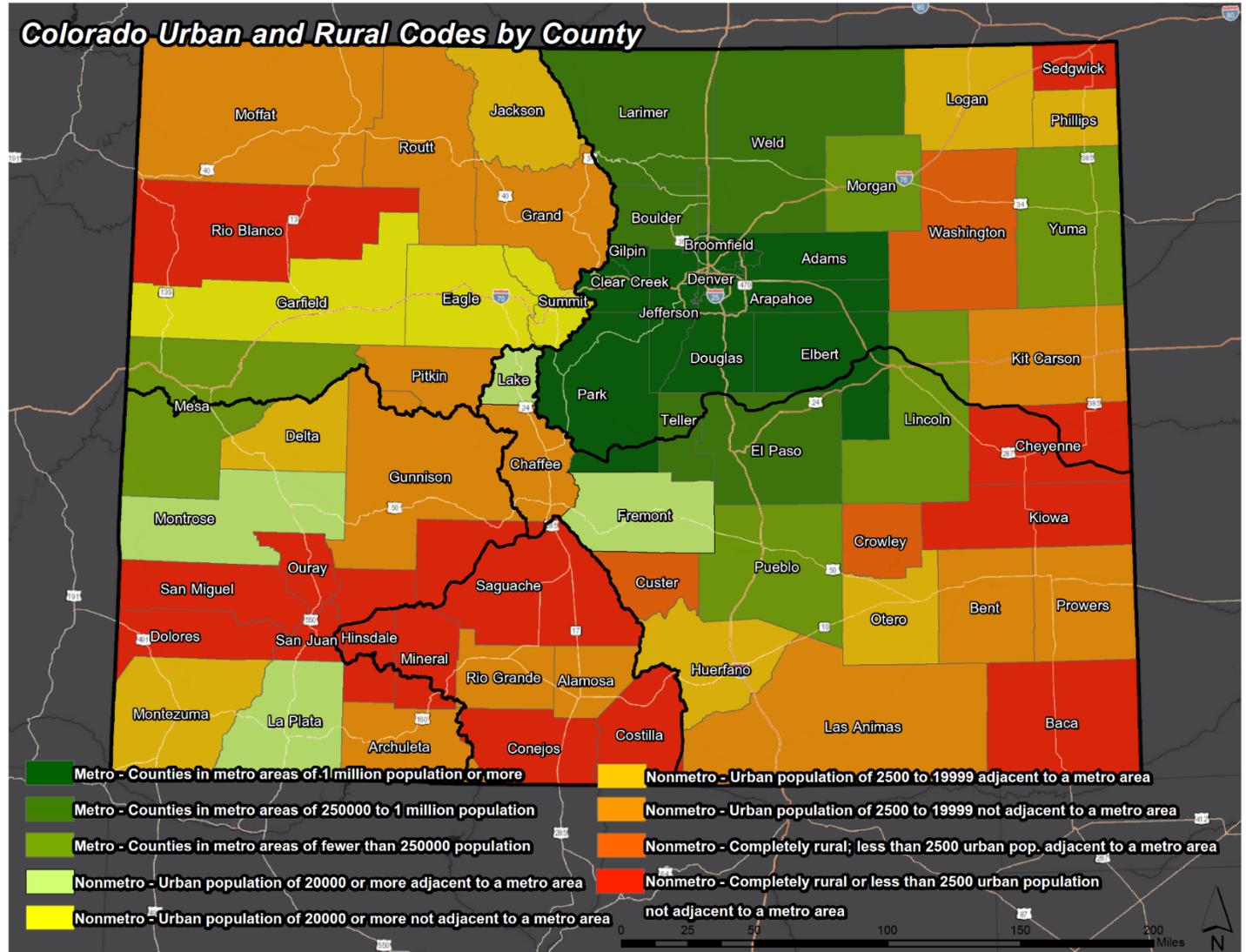
their own water supplies on-site, and often connected to regional power grids by single transmission lines. In mountainous areas, transportation can also present serious challenges, as floods, fires, and extreme snow storms can quickly block or destroy roads entirely.

In addition to limited access to these essential services, many rural areas are also isolated from universities and other institutions that can provide specialized training. In Colorado, the Colorado State Extension Service and various USDA programs have long attempted to bridge this gap. Nevertheless, many areas remain disconnected from the scientific innovation and inquiry that is concentrated within Front Range cities.

Socio-economic Vulnerability

Rural communities may also face greater than normal

challenges due to issues such as poverty, low educational attainment, or aging populations. While some rural areas show high levels of wealth - for example, Aspen, Vail, and to a lesser extent, Steamboat Springs - many communities must deal with higher than normal

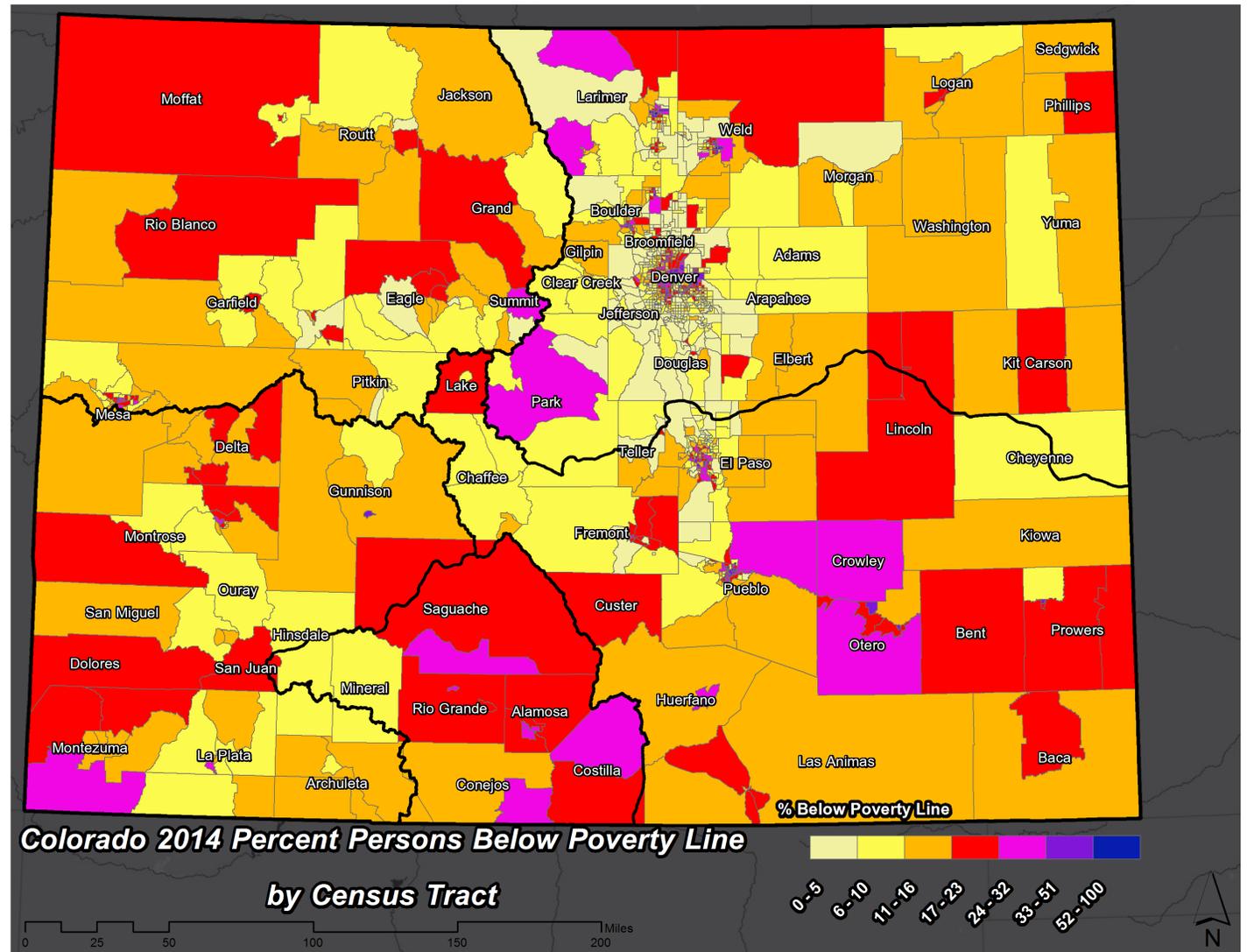


Map 4 - "Rural" is a matter of degrees. The USDA utilizes the above coding scheme. Areas in orange and red are generally the most isolated, sparsely populated, and furthest from cities.

levels of poverty, limited economic development opportunities, and minimal options during times of weather-related stress. In some areas, particularly in the southern and central Eastern Plains, population levels have fallen as younger generations move to nearby cities and elderly residents die off. Many rural areas in Colorado are also undergoing rapid demographic change due to immigration, which may hinder efforts to communicate and coordinate around natural resource and weather-related issues.

Resource Access and Weather

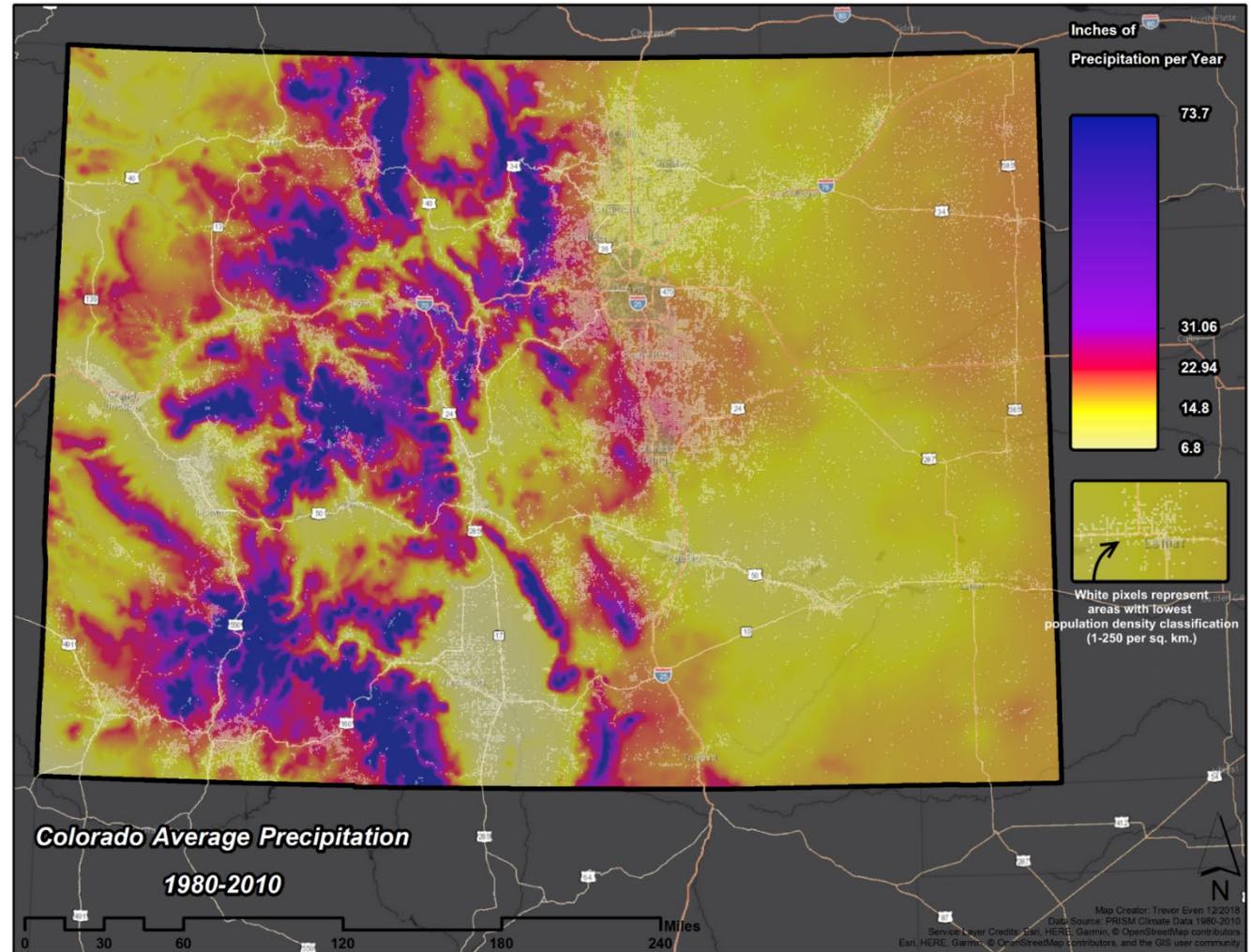
Many rural communities in Colorado must deal with the seemingly paradoxical distribution of ecological resources that characterizes the state. With most of the state's water supply located in high elevation areas, and most of the viable lands for farming, ranching, and living located in lowland areas, tremendous effort must be undertaken to move water to where it is needed and valued most, and to manage that water as it moves



Map 5 - Poverty and other socio-economic problems are no strangers to rural Colorado. At the same time, many rural areas have high levels of financial and other forms of capital. However, even in wealthier areas, small pockets of low income citizens are common, creating an increased likelihood for negative impacts following extreme weather events.

across and out of the state. Because of this, droughts can have effects that span well beyond the localized areas in which they occur. Likewise, water needs downstream can affect water users elsewhere, due to the state's complicated system of prior appropriation water law. While groundwater resources are available in many areas, these resources are non-renewable, and are prone to collective overuse, particularly during drought periods. Many rural areas - particularly those in the eastern half of the state - face significant pressure to sell agricultural water rights (which may be "senior" due to having been passed down for decades through families and specific farming operations) to growing cities along the Front Range.

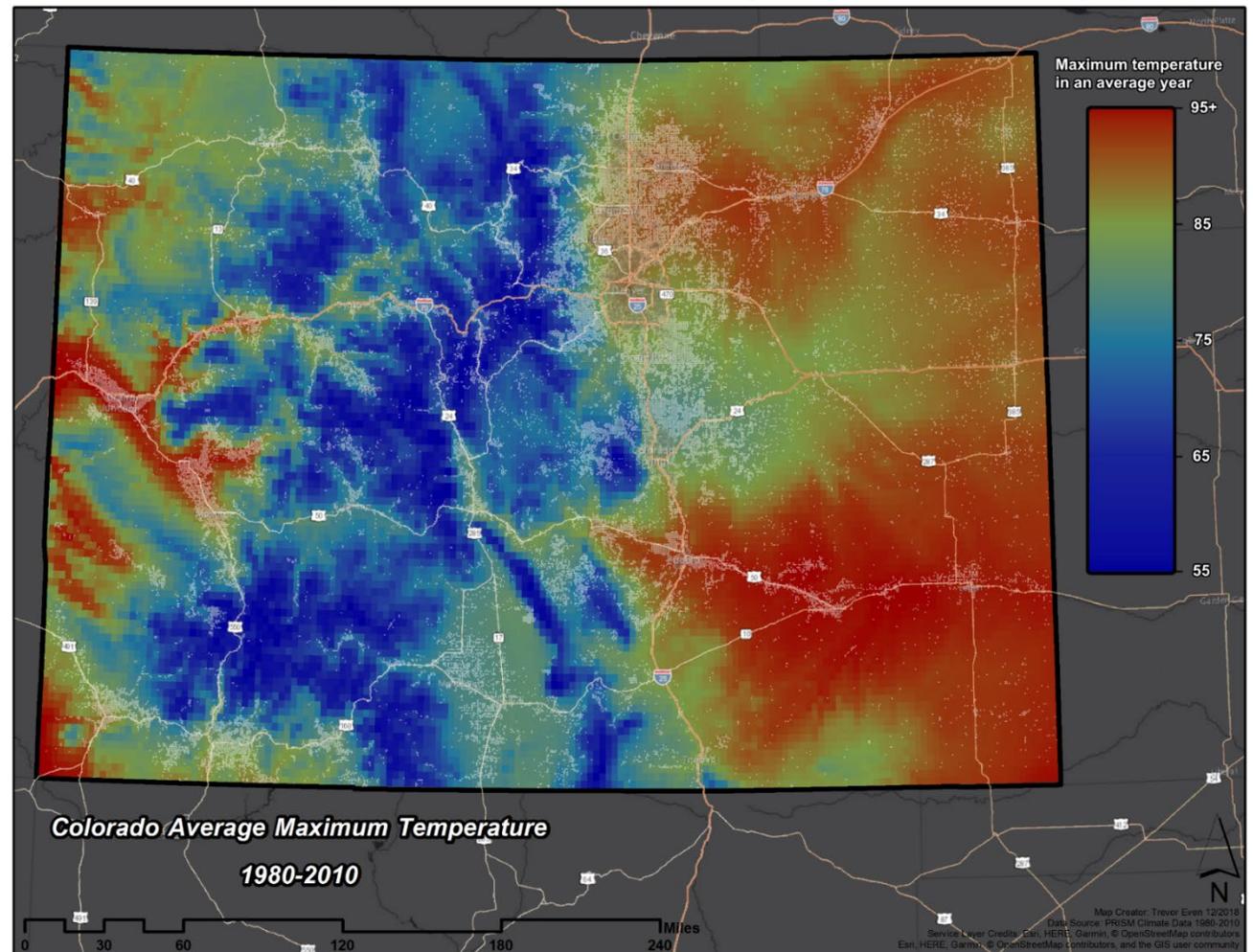
At the same time, rural areas may also face heightened exposure to certain weather-related hazards, such as wildfires, hailstorms, tornadoes, and extreme precipitation events. Mountain communities, for example, may have access to majestic natural beauty and valuable recreational resources. During drought periods, however, these prized landscapes present serious risks in the form of wildfire and subsequent flash-flooding due to those same resources entering a volatile state. In the plains, broad, flat lands suitable for farming and ranching face high winds and extreme storms, and are highly vulnerable to both local droughts and failures of snowpack. Without snow in the mountains, plains and valley communities may be forced to go without the water



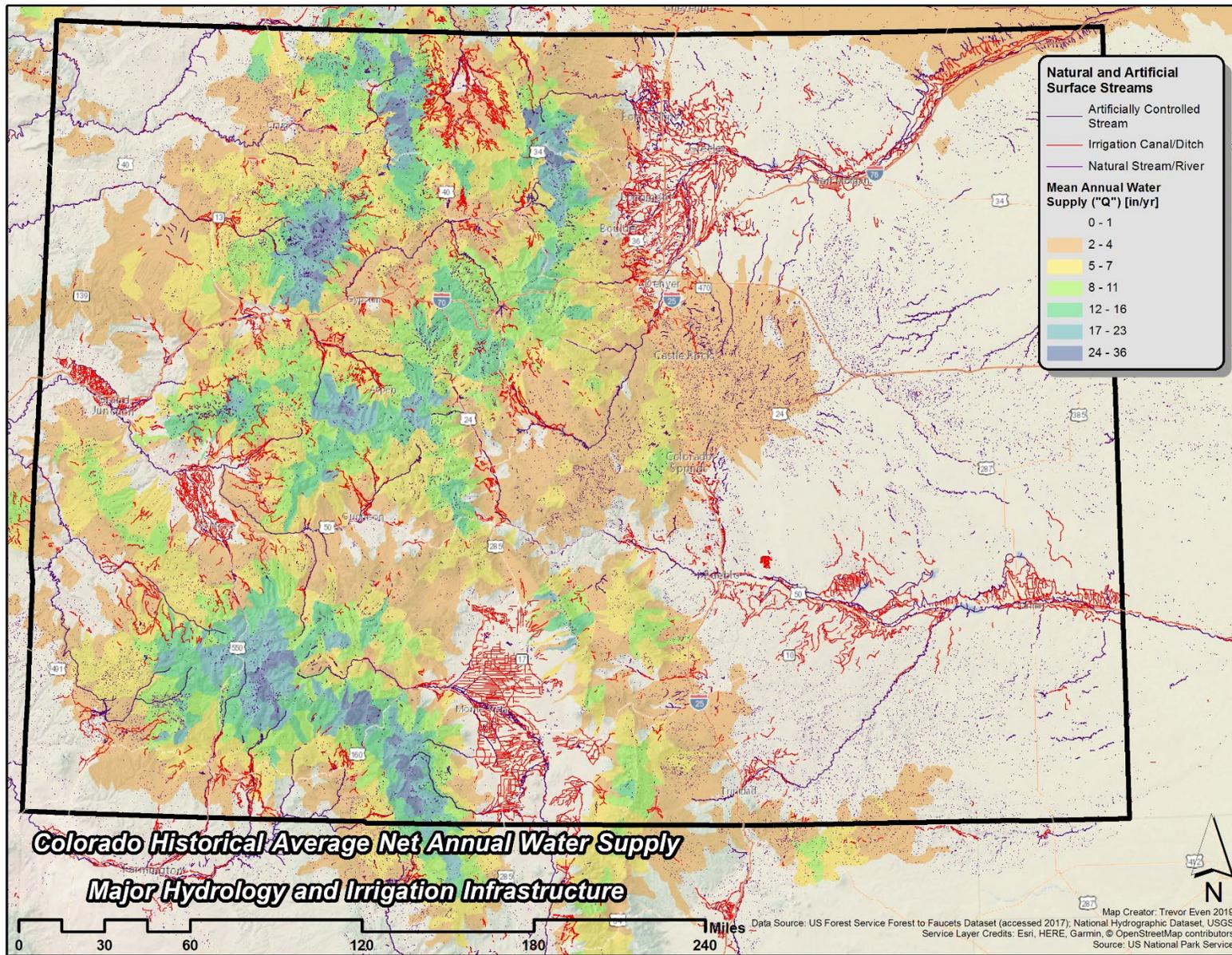
Map 6 - Precipitation from the PRISM global dataset. Many rural areas in Colorado receive very little native precipitation, and must rely upon groundwater and surface streams to meet their water needs.

they rely upon for human consumption, irrigation, and livestock. Many rural areas also see high temperatures during the summer, which may result in negative impacts to human health as well stress to crops, livestock, and the native vegetation that livestock rely upon. In the 21st century, many of these areas have also seen an increase in days with temperatures above 90 degrees as part of the overall trend of rising temperatures across the state.

While cities along the Front Range may be able to invest in complex infrastructure to reduce water usage and improve water transmission efficiency, many rural areas face degraded or aged infrastructure issues at both municipal and industrial levels, and may rely upon irrigation systems that have been in place for almost a century. Though these systems are critical to agricultural livelihoods, especially, complex issues surround their improvement and maintenance further heightening risks from weather shocks to rural communities.



Map 7 - Temperature from the PRISM Global Dataset, averaged over the period of 1980-2010. Because rural communities often rely directly upon the land for their economic well-being, high temperatures can result in losses well beyond the cost of additional air conditioning.



Map 8 - "Q", a water supply metric that subtracts water lost to evaporation from average annual rainfall. (Provided by the USFS Forests to Faucets Program). Irrigation is critical to rural livelihoods, but many areas face serious issues in maintaining this infrastructure (shown in red here).



Photo 1 - Trout Lake, near Telluride, CO. Taken Credit: Alex Berger, 2013.

Effects of Extreme Weather and Disasters on Rural Livelihoods

In the previous chapter, we looked at some of the broad, statewide changes in weather that are shaping Colorado in the 21st century, drawing on a variety of scientific sources and weather monitoring information providers across the state. However, to truly understand how these changes in weather are impacting everyday Coloradoans, it is important to look beyond broad trends, and to understand how people living day-to-day with weather impacts are perceiving and responding to these changes. This is particularly true when considering Colorado's hundreds of small rural and mountain communities, where livelihoods and ways of life are often tied closely to surrounding lands and their response to various weather conditions. In this chapter, we attempt to capture some of the stories being told about the weather in rural Colorado today, bringing together information from personal conversations, news stories, and other on-the-ground research projects examining these issues. Our question here is straightforward: How is changing weather affecting rural Colorado communities?

Even beginning to answer this question, as we will see, is rather complex. To simplify matters, then, we focus on three distinct - but often overlapping - livelihood sectors: agriculture, ranching, and outdoor recreation, including hunting, fishing, river rafting, skiing, and various other outdoor activities. We do this, primarily, because these are livelihoods known to characterize the economic backbone of many rural communities across the state, and moreover, are often central to the values and ideals of many who choose to live in rural

communities. From a scientific perspective, however, these livelihoods are especially interesting when considering weather impacts, as they are all united in their close relationship with the vicissitudes of the surrounding environment and the weather that shapes it. Whether a business owner is guiding tourists down a raging river, moving cattle to new pasture, or planning next year's crops, they must do so while always carefully considering what weather is going to give them - and what it might take. As a result, the perspectives of those engaged in these "land-based livelihoods" represent news from the "front lines," so to speak, in the state's attempts to come to terms with the risks, challenges, and opportunities that changing weather patterns present.

In the following sections, we present findings from our research into each of these three broad sectors and attempt to highlight some of the unique features of each that have allowed recent shifts in weather to present distinct challenges to them. That said, while the concerns of particular businesses and business types may vary - especially when taking into account the varied landscapes across Colorado on which they occur - it would be a mistake to assume that these sectors live and breathe independently. On the contrary, in many rural communities across Colorado, farming, ranching, and various recreational livelihood strategies often go hand in hand, both within a given town and, at times, within specific families. This is doubly true for the landscapes that these livelihoods rely upon, as much of Colorado's land-based livelihood community utilizes lands that serve multiple purposes, at times with multiple parties being involved. This complexity is most distinctly felt in the central mountains and western slope, where public lands administered by the U.S. Forest Service and Bureau of Land Management form a critical component of the region's natural resource base. Here, recreation, agriculture, and ranching often closely overlap as tourists, locals, livestock, nearby farms, and wildlife all vie for their part of resources scattered across a patchwork of private and federally-managed lands. As a result, while some of the impacts we will discuss may be specific to a given industry, for those who depend upon the economic vitality of rural communities, they never occur in isolation.

Ranching

Ranching has been a long-standing livelihood in Colorado, and the people and livestock that make it possible have played an at times out-sized role in shaping the state's history, law, and general settlement patterns. Currently, over 20 million acres statewide (roughly 1/3 of the state) are used as pasture for cattle, sheep, goats, and other livestock, generating around \$5-6 billion in cash receipts each year, and playing a powerful role in the state's \$40 billion+ agriculture and food production sector.^{1,2} As weather patterns change across the state, ranching operations - some of which have been in operation for 100 years or more - are finding themselves facing new challenges, from adversaries both old and new. Generally occurring on lands that are too dry for production agriculture, too rugged for easy navigation, or too remote for large settlements, ranchers in the state have always dealt with difficult circumstances and have had to deploy all manner of strategies to maintain healthy herds when rains fail, grasses wilt, and water sources dry up. In recent decades, however, cattle ranchers and other livestock herders across the state have found themselves dedicating more

and more resources each year to addressing weather related risks, both from disaster events relating to extreme storms, flooding, and wildfire, as well as due to long-term drought trends. When these costs become too great, they can upset even the most resilient operation, and can have serious negative impacts on rangelands, cattle, water resources, ranchers themselves, and the communities they live in.

By far the most serious risk faced by Colorado ranchers is the increasing trend towards more intense and frequent drought episodes, as droughts can set in motion a number of different process which, while difficult enough in isolation, can converge to utterly devastate ranching operations. The primary impact site during drought for rancher, of course, is the landscapes that they rely upon for grazing, and the numerous different plant species and other resources that they contain. When drought conditions set in, grasses produce more slowly or not at all, and natural surface water resources become unreliable. As a result, grazing lands also become more fragile, and more sensitive to long-term degradation due to grazing activity. Because of this, during times of drought ranch operators must search for supplementary feed and water resources, as well as spending more time monitoring and moving cattle to ensure that what local resource pools are available to not become over-stressed. Each of these activities bear with them additional costs, even under the best of times, in the form of both labor and capital.

Indeed, during extensive drought periods - which often occur across numerous counties and states, prices for feed can increase prohibitively as other nearby ranchers also scramble for the resources they need to maintain herd condition. As a response to these stresses, both economic and environmental, ranchers will often choose to sell off part of their productive herd. But while this can reduce stress in the short term, due to having less cattle to manage and feed, in the coming years this reduced productive capacity means lower potential returns. Likewise, selling productive stock can also reduce the overall genetic robustness of the herd, further compounding long-term drought impacts as ranchers struggle to re-grow their diminished livestock numbers. Even for those ranchers who dedicate some of their land to growing supplemental feed - and who may, ostensibly, benefit from high prices during some drought conditions - often find that these measures also fall prey to the lack of water and high temperatures that have become more common in recent years.

As current drought conditions set in, variations of the same story are being told once again across much of the state. As one observer near Ordway put it, rather bluntly: *“Area ranchers are starting to destock. Feed is getting harder to find locally. Desperation point has*

Photo 2 - Cattle graze near Powderhorn, CO. Credit: Unknown.



*been reached.*³ Similarly, southwestern Colorado rancher Matt Isgar noted while speaking to Colorado Public Radio this summer that the cost of ranching is climbing as soil moisture and landscape productivity fall: *“We’re spending more material and labor fixing fences and hauling water, and we’re supplementing with protein [to offset the poor quality of natural vegetation]. So every day is more expensive to operate.”*⁴ Statements like these, common across the state’s ranching community, are also echoed in some ranchers’ perspectives on long term trends. One sheep and cattle rancher operating in Moffat County in northwestern Colorado described to researchers working for the Bureau of Land Management how the character of drought episodes has changed since the early 2000’s, noting that:

*Until this last 5, 10 or 15 years of drought, usually a drought around here didn't last more than a year or two. So you didn't really see that spike and drop in the [price of] hay. But it's got more challenging the last 10 or 15 years after 2000-2002 drought. Things really have never ... We haven't got out of it and I really think to a certain extent in my own mind that we've been in a drought since the early '90s. Yeah, there's been good years and there's been a few bad but they've been more bad. You've watched springs run dry[...] Even like the Little Snake, it doesn't flow what it used to flow.*⁵

Drought, however, can also increase risks for other hazards to occur, the most dangerous of which is wildfire. Across the state, wildfires large and small, driven in large part by drought conditions, have impacted the lives of ranchers in a variety of ways. Some of these impacts are direct, with wildfires damaging or destroying homes, outbuildings, or equipment; others are more indirect, with wildfires affecting the availability of forage and requiring a variety of costly measures to protect the lives of their families and livestock. And while, statewide, wildfire risks tend to be at their greatest in the heavily forested, high elevation areas of the state, out of control fires occurring in lowland areas have also proven increasingly dangerous to Colorado ranches and nearby communities.

Case in point, the Mile Marker 117 fire, which began in 2018 - likely due to sparks from a passing vehicle - somewhere just southeast of Colorado Springs, near the small, dispersed community of Hanover. Within 24 hours, over 40,000 acres would burn, stretching from the cottonwood-lined banks of lower Sand Creek near I-25 to prairies and ranchlands 20 miles to the east. Driven by extreme winds, high temperatures, and pervasive drought conditions, the fire would present significant challenges to local and county firefighters dispatched to the

Photo 3 - Bulls vie for dominance near La Veta, CO. Credit: Larry Lamsa, 2014.



Fire on the Southeastern Plains

Part of a large extended family of Colorado homesteaders with deep roots in the ranching and agricultural sectors, T__ E__ runs a successful landscaping business in Colorado Springs. In the last several years, he had been slowly working to establish his own ranch just outside of Hanover, located roughly 30 miles north of Pueblo. Having had extensive experience with post-fire remediation and planning for wildfire risk as a landscape technician, he worked to make sure that his home and property were clear of debris, well irrigated, and isolated from dense vegetation. Nevertheless, when the 117 fire erupted, he ultimately found himself able to do little but watch as his home caught alight as he attempted to defend his ranch's outbuildings from encroaching flames. Though he was able to save his herd, and much of his equipment, the home he and his wife shared was completely obliterated. As he related to a local news station: "I just froze ... I could tell that our house was on fire and just the shock of it... the firemen said there was nothing they could do. It was already burning up in the attic" Though he plans to rebuild, he hopes that in the future firefighters and area ranchers will be better able to cooperate and share information on the location of hydrants and other critical infrastructure, which can often be hard to discern in minimally developed rural areas.⁶

area, where a lack of familiarity with the area and a scarcity of readily available water forced them to pick and choose their battles amid hostile conditions and on-going dust storms. Less than two days after it began, the fire would cause over \$1.3 million in damage, destroying 18 homes and 21 outbuildings, several among which were small farms and ranches whose entire land holdings were likewise incinerated.⁶ As one resident of the area related to a Colorado Springs television station, the intensity and pace of the fire - as well as the hostile weather conditions that led up to it - made even finding the charred remains of her home a challenge: *"The wind, the smoke, and the sand, it was hard to see what was left of the house. I can't rebuild out here. I don't have enough money to do that."*⁷

And while in years past such a large, destructive, and rapidly growing fire would likely stand out for some time to come, the dry, hot conditions across the state in 2018 would mean that the 117 fire would soon be eclipsed by numerous others across the state. Indeed, as the summer set in, several large fires across the state began to burn, among them the Spring Creek Fire, which would eventually burn over 108,000 acres of mountainous,

forested land between the small ranching and farming towns of Fort Garland and La Veta.⁸ Although started by human activity, the Spring Creek fire would grow primarily due to vast amounts of nearby drought-parched forest and strong, whipping winds, creating conditions that some fire professionals described as "a tsunami of flame."⁹ By the time of its containment - more than a month after it began - it would destroy over 140 homes, displace thousands, and involve almost 300 full time fire-fighting personnel and 1,800 emergency responders (Inciweb 2018; Kackley 2018).¹⁰

For local ranchers and home owners in the area, however, the Spring Creek fire would bring more than economic costs. For some, it meant losing memories, knowledge, and labor embodied in the working landscapes they had cultivated over decades. This was the case for the Morgan family, who, as they related to the Denver Post, found themselves faced with the total devastation of their family ranch and cemetery after the Spring Creek fire swept through their property in mid-July. *"That was always Grandma's house for all my kids and all my*

nieces and nephew, too [...] So that's why it's so hard on them not being able to experience that. It's a different way of life now." Another family member, coming home to see the family land after living out of state put it differently: *"The land is what shocked me. When we walked up to the cemetery and up through the land, I couldn't recognize it. It was like walking on another planet. It was just burned to dust."*¹¹

For other working ranches, however, the loss of homes, mementos, and cherished landscapes came with the added burden of needing to care for livestock, both during and after the fire. With ranchers in many cases being forced to round up herds, arrange for alternate pasture, move animals across long distances, and pay for supplemental feeding, the combination of persistent drought conditions and charred pastures meant that significant resources had to be expended simply to keep the possibility of recovery that their herds embodied available. As a result, even in cases where livestock are not lost directly to fire, lingering effects on the landscape can continue to drive up the cost of making a living in ranching for years to come.

This is especially true in the western regions of Colorado, where ranching livelihoods are often closely tied to the availability of public grazing lands managed by the State of Colorado, the USDA Forest Service, or the Bureau of Land Management. When drought and associated wildfire conditions occur in these areas, pastures that are normally available for grazing - as well as a variety of other activities - may be restricted by the relevant agency in order to maintain ecosystem integrity and allow for landscape recovery.¹² Because of this, ranchers and other livestock operators in the western portions of the state often face heightened impacts from drought conditions, above and beyond those normally experienced by those relying exclusively upon private lands. For while all lands, public or private, may see reduced forage availability when water is scarce, careful management and livestock movement can allow livestock operations to continue at reduced levels. On public lands, however, restrictions are often total, with no access to whatever reduced grazing resources remain. Similarly, lands may also be closed off to public use if wildfire risk is high enough, regardless of whether or not specific grazing allotments have actually burned. Indeed, in the northwestern part of the state - particularly in the Moffat, Routt, and Rio Blanco areas, where livestock production is relatively high - impacts from drought and wildfire can have serious impacts on the viability of livestock operations. Given that, as of the early fall of 2018, several large wildfires (e.g., the Ryan, Silver Creek, and Weston Pass fires) continued to burn, without significant increases in precipitation over the coming winter it is likely that many livestock operations in Western Colorado will face, at the very least, dramatically increased losses due to costs associated with hauled water, supplementary feed, and sub-optimal sell-offs of herds. At worst, already vulnerable operations may be forced to either reduce operations substantially, or simply terminate their operations altogether.

Farming

Farming, like ranching, has long been tied to the economy of Colorado, and has played a role in the development of all but the most high elevation settlements in the state, shaping local history, culture, and infrastructure development in ways both dramatic and subtle. Currently, Colorado farms generate between \$2-3 billion in production each year from a range of crops

including specialty items like hothouse tomatoes, cantaloupe, and potatoes, as well as more common staples like wheat, corn, and sorghum. In terms of pure land area, approximately 10 million acres (roughly 16.5% of the total land area of the state) are involved in some form of crop production as of 2017, with the largest acreage totals per crop belonging to winter wheat, corn, alfalfa, sorghum, millet, and hay.¹³ However, as with most aspects of Colorado, statewide averages and totals only tell part of the story. Depending on which region of the state one looks to, the role of crop production - as well as which crop types dominate - varies substantially, with the San Luis Valley and Grand Junction areas relying heavily on specialty crop production, staple production dominating the landscape in the eastern plains, and alfalfa and other livestock feed crops playing a critical role in the numerous other rangeland dominated areas of the state.

Similarly, while farms (including ranches) only represent around 1-2% of the state's employment totals, (approximately 43,000 jobs in 2016¹⁴), in many communities the incomes generated by farms - as well as the need for supplies and equipment - provide the backbone of the local economy. Indeed, a drive through any of the many small to medium sized towns outside of the urban front range tells this tale all too well, with small "main street" rows of domestic storefronts often ringed round by feed depots, ranch and farm equipment dealerships and repair shops, plumbing and construction supply outlets, and a variety of other agriculture-focused services, the sum of which, in many cases, comprises the entirety of a given region's opportunities for employment. Likewise, while rural towns in the state's mountainous areas are "hybridized," with recreational tourism, ranching, farming, and service industries each playing a role in local economic life, in all but a few of the rural communities in the eastern plains agricultural industries dominate both the surrounding landscape and the local social fabric. Because of this, the effects of destructive storms and drought to farms and farmlands can have impacts that reverberate beyond the confines of a particular farmer's acreage. That said, when hostile weather conditions occur, it is ultimately farmers and their families that bear the brunt of the negative outcomes.

But while farms may vary from region to region, and may differ in their ability to withstand weather impacts due to the decision-making skills of individual farmers and the specific crops they grow, one truth reigns supreme throughout Colorado's agricultural community: namely, that without *water*, there can be no crops. For farmers who produce non-irrigated, or "dryland" crops such as winter wheat, times of drought due to low precipitation or extraordinary heat can spell the end of a given year's ambitions as soil moisture levels rapidly

Photo 4 - Exurban/semi-rural housing outside of Lafayette. Credit: Let Ideas Compete (Flickr.com), 2010



following planting season. When drought conditions are severe, the number of farmers who find themselves in this position can grow rapidly, with at least 165 calls on Colorado rivers as of September 2018, and 76 still active in November.¹⁵ In some areas on the in the southwestern portion of the state, this has led to fruit growers spending hundreds of thousands of dollars buying water allocations from senior water rights holders, at times resulting in conflicts with local water and ditch company managers, and sparking fears that a failure in snowfall in the on-coming winter could result in a need to re-evaluate the sustainability of their businesses. As one corn, onion, and bean farmer near Olathe put it, *“This here is a tough racket, and this year is a tough one, for sure. We knew going into this season that we had enough water storage for the crop this year. What we don’t know is if we’ll have that next year. If we don’t have water, it would devastate this valley. I’ll just turn in my keys to the man at the bank and let him give it a go.”*¹⁶ Even when farmers are able to weather the dry years - whether through crop insurance, federal programs, or careful saving and planning - long-term effects on soils can further hinder efforts to replant, particularly if drought conditions persist through the winter. In these cases, soils may remain without the necessary moisture for plowing and planting in the early spring.

For specialty crop growers producing tree crops like peaches, plums, pears and apples, however, drought impacts can mean the loss of trees that often represent years of investment and care, either through direct mortality due to lack of water, or through the weakening of the tree’s ability to fend off pests and disease. In other cases, early warming in the spring time - so called “false springs” - can lead to fruit trees budding early, which, when late frosts occur, can cause almost total losses as the fragile flowers are damaged. As Keven Kropp, a cherry farmer on the western slope put it in 2015: *“It’s every fruit-growers nightmare to have the combination of an early bloom with potential cold-fronts coming through later on in the season.”*¹⁷ Another fruit farmer in Paonia, speaking to the Delta County Independent in 2017, noted that, due to both early

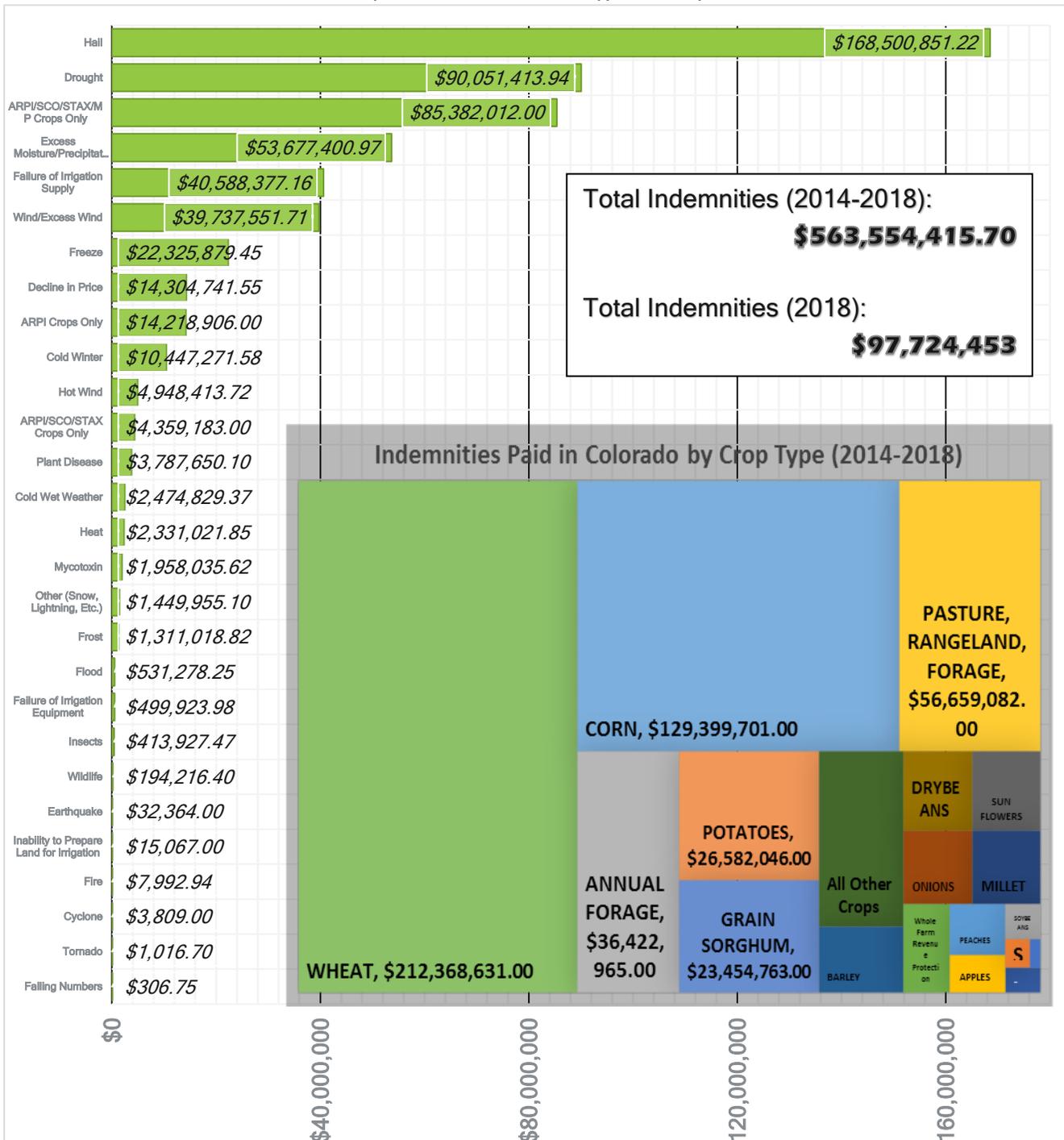
Flooding and Small Farms: Bethie S.’s Story¹⁷

A lifelong student and small time farmer who made her home just outside of the small farming and tourist town of Lyons, Colorado, Bethie S. was living the dream: with 11 acres of raspberries, pumpkins, and other specialty crops, she, her son, and business partners had been able to make a modest living off of what had long been her personal passion. Utilizing a small herd of goats for weed mitigation and llamas for herd protection, she and her partners envisioned an agritourism business that would allow local community members to enjoy the idyllic beauty of their streamside working farm. When rain began to fall in early September of 2013, however, much of her dream would soon become little more than a memory. While at first it seemed the small plot of land would escape the worst impacts being felt by others in the region, as rains intensified on September 12th and nearby streams swelled to unrecognizable size, she scrambled to gather her animals and valuables to safety before almost succumbing to the rising waters herself. Although able to rescue several animals, the slow slog of recovery and the area’s skyrocketing housing prices would ultimately mean that she would have to give up for adoption the few animals she was able to salvage, and give up on the hopes of restoring the farming lifestyle she had worked to cultivate. Deciding instead to return to school to study sustainable agriculture, she now works through a non-profit agency to teach young farmers about traditional agricultural practices from around the world.

budding due to warming and the unpredictability of recent last frost dates, the fruit farming business was requiring the deployment of increasingly complex methods for fending off freeze damage, including installing large scale outdoor air circulation machinery. Reflecting on 20 years of experience in the area, he recalls that, if one were to talk to old timers in the area, “they’d tell you they always had a cherry crop. Now it’s the opposite. Everybody’s scrambling.”¹⁸

Regardless of crop types, however, changes in the onset of spring can bring challenges to farmers, even when the previous year’s winter precipitation is at or above

Figure 3 0 - USDA Risk Management Agency Crop Insurance Payouts in Colorado (2014-2018) by Cause of Loss and Type of Crop.



normal. For dryland farmers, early springs can mean that the soil moisture needed to make soils loose enough for planting may dry out before the last waves of cold temperatures have passed, resulting in soils that are difficult to penetrate when planting time finally arrives. Likewise, reductions in soil moisture early in the season can mean that crops are not able to germinate and accomplish early season growth as effectively.¹⁹ For farmers who rely on irrigation, on the other hand, these issues with soil moisture can be exacerbated by early snowmelt in upstream watersheds that move water stored in snowpack downstream too early to be useful for irrigation purposes. And because water rights for irrigation are often associated with specific times of year, in years with particularly warm springs farmers may find that waters that they may, in the abstract, possess rights to use are already well on their way out of the state.²⁰

But while a lack of expected water - both at the specific times when it is most needed and in the more general sense - may be among the most deeply crippling outcomes of Colorado weather for the state's various farmers, too much precipitation can prove equally destructive. In 2013, when massive rainstorms brought several months' worth of precipitation to foothills and cities of the northern Front Range in a matter of days, much of the nation turned its attention to the numerous cities and mountain communities that suddenly found themselves inundated and cut off from the outside world. However, as flood waters made their way downstream, bringing with them tons of debris, silt, chemical contamination from up-turned oil and gas facilities, raw sewage from inundated treatment facilities, and biological contaminants from cattle processing and feedlot facilities, a much quieter catastrophe was unfolding in the fields of operating in the lower South Platte Basin east of Greeley. There,



Photo 5 - Extensive flooding in 2013 affected large areas of Weld County, including thousands of acres of farmland. Credit: US EPA 2013

flood waters would bring around \$5 million in direct damages to crops as over 25,000 acres of farmlands sat under stagnant water, in some places for almost a week.²¹ And although exact numbers are not available, numerous reports of significant damage to farmsteads, equipment, ditches, fences - as well as lingering fears about contamination of crops that remained viable for harvest - likely resulted in millions more in costs to farmers in both direct damages and subsequent losses due to the inability to plant in the following season, with some state reports at the time estimating around \$60 million in damages to irrigation infrastructure alone.²² Adding insult to injury, because many of the smaller farms found scattered along the foothills relied heavily on local farmers' markets and organic, locally grown marketing strategies, fears of contamination and the closure of many markets drove down profits even for those who were able to salvage the year's sodden harvest.²³

Beyond spectacular events like the 2013 floods, however, changes in the nature of the state's precipitation patterns can also have serious impacts on farmers that have relied upon the region's normally frigid winter temperatures to keep their fields and winter wheat crops free of disease. With more early spring precipitation falling as rain rather than snow, however, risks from disease like stripe rust have been noted in many areas during particularly wet spring years.²⁴

Precipitation can also take a debilitating toll on agricultural operations when severe storms develop that result in the formation of hail. Such storms have long been a lamentable feature of Colorado's late spring and early summer weather patterns, with the vast majority of events occurring in the eastern regions of the state.²⁵ When combined with the driving winds that often accompany hail-forming stormfronts in the region, otherwise healthy crops can be reduced to nothing in mere minutes. In addition to direct destruction of crops, these storms can cause "lodging," or the breaking of stalks and failure to seed in wheat crops. If these storms occur early enough in the season, farmers may have a chance to replant their fields and hope to recover their losses. However, should hailstorms occur later in the growing period, losses may be total. As William Harman, a Logan County corn and sunflower farmer related to Denver's 9 News in 2017, late season hailstorms can result in the near total loss of a year's work, with even minor hailstorms able to significantly degrade yields through damage to sensitive plant organs: "*You put in a lot of work to get to this point, and it's all ruined in minutes... The corn was tasseling and pollinating, and that's a very crucial time. [Hail] breaks the tassles and the silk off, and the corn cannot pollinate properly. The sunflowers were budding, just getting ready to bloom, and yeah, it was about the most critical time it could hit.*" As a result, his farm would see roughly \$200,000 in losses, with only insurance and the hope of better luck next year to brunt the costs.²⁶ In 2018, a similar tale played out on the Hultrom farm located outside of Broomfield, when 200 acres of corn was reduced to ribbons in minutes. As Hultrom told KDVR reporters this July, "*It's the worst storm that I've had... to lose it all in about 15 minutes, it is tough. It's all gone.*"²⁷ Similar reports have also come in from across the state, with some loss estimates for the 2018 crop year ranging into the tens of millions statewide.²⁸

As a result of the long-standing risk of hail damage on the eastern slope of Colorado, many farmers take out insurance policies designed specifically to offset these risks, provided either by various federal government programs or private insurance companies. However, these are seldom designed to recover all losses associated with hail damage, and often pay

out on a percentage basis depending on the value of a specific crop and how close to harvest it was when destroyed. Most policies are also written only for individual crops, meaning that small, diversified farms that serve local areas can be particularly vulnerable to large hail events due to a lack of insurance.²⁹ Insurance programs can also “max out,” or reach annual payout limits due to successive destructive events, leaving farmers to deal with the tattered balance. This was the case for Hiramata Farms, a pumpkin and melon operation located in the small southeastern town of Rocky Ford. Having been prevented from planting during the spring of 2017 due to severe thunderstorms that left their fields unsuitable for furrowing, they tapped into funds available through the Noninsured Crop Disaster Assistance Program (or NAP), a program run by the USDA to support “non-insurable” crops like melons and other specialty products not covered by other major crop insurance outlets. Later that summer, however, those crops that they were able to get in the ground during the shortened planting window were severely damaged by hailstorms and straightline winds. When applying for additional NAP funds, they were told that they had reached their maximum allotment of payments for that year. As a result, the farm would see more than \$300,000 in losses, a burden only heightened by this year’s lingering drought.

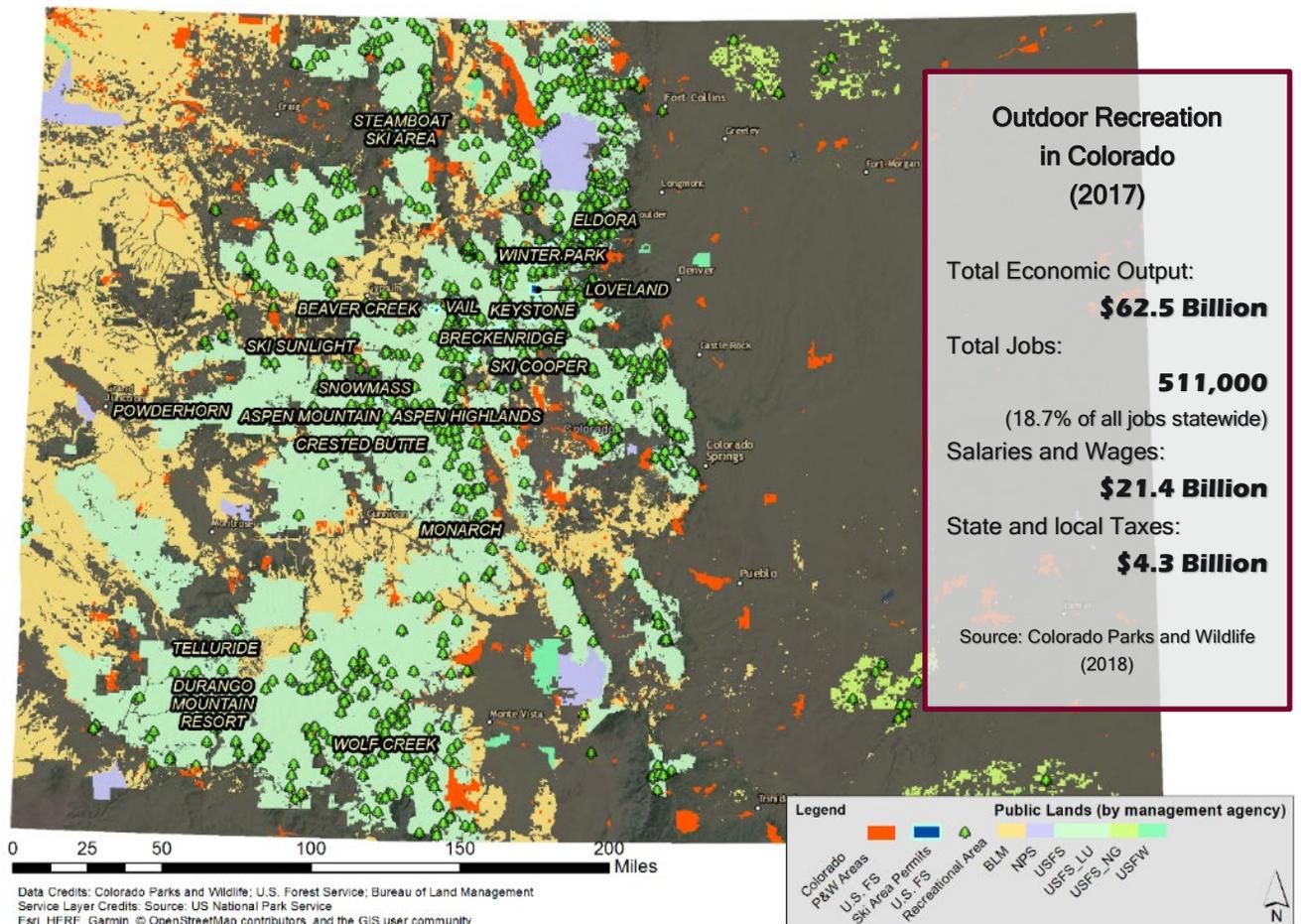
To sum up, farmers provide an essential support to the rural communities of the state and face significant challenges to the viability of their livelihoods as a result of changes in weather intensity and variability. In some cases, this is a matter of too little water and too few of the social, technical, and economic resources needed to ensure its availability during times of scarcity. In others, it is a matter of too much water, be it in the form of floods or snow melting too rapidly to be of practical use throughout the season. In still others, weather brings direct destruction to crops and the land. In general, however, it is the increasingly unpredictable way in which these different challenges present themselves that poses the greatest challenge, as it hampers efforts to make adjustments that might help to reduce risks. As Michael Hiramata, the director of Hiramata farms put it, when asked what it means to be a farmer dealing with Colorado weather: *“Weather is getting more extreme. Though it has always varied from year to year, and every year has brought new challenges, the weather in the last 10-15 years has brought more variability than we’ve ever seen.”*



Photo 6 - Haystacks at a ranch near Kremmling. Credit: Grant Matthews (Flickr.com), 2017.

Outdoor Recreation and Tourism

Best estimates of the current population of Colorado come in at around 5.5 million people. In 2017, roughly 38 million people visited the state for one night or more, half of which travelled more than 500 miles to do so.³⁰ Of these, about a quarter are estimated to be here to visit the state's growing cities, their business networks, and various casino resorts along the Front Range.³¹ The rest - or just under 30 million visits - come for reasons that anyone who spends any amount of time here will easily identify: namely, *we live in a breathtakingly beautiful state*. Whether one looks to the stark prairies, wandering canyons, and desert dunes of the western slope or to the humbling peaks and forests that form the state's backbone, Colorado is known the world over as a place worth visiting. Its natural wonders call out to even the most stubborn advocate of indoor living at least once in a lifetime, and more often than not experiences in the wild lands of Colorado come to play an important and cherished part in the lives of those who call our state home. As a result, while it is important to account for the massive economic impact of the vast and varied "outdoor recreation sector," it is equally important to understand



Map 10 - Recreational land resources in the form of public lands, public recreational facilities, ski slopes (with names in all caps), and National Parks are concentrated heavily in the Western and mountainous areas of the state. Not pictured here: the state's world famous rafting courses scattered across the upper Colorado, Yampa, Gunnison, Arkansas, and other rivers, nor roughly half a dozen privately-owned ski areas.

that outdoor recreation - whether in the form of simple leisure activities like skiing, hiking, and camping, or more complex activities like fishing, hunting, environmental education, and river rafting - are an important part of what Coloradoans value about their state, and in many cases, a critical part of the local cultural fabric of local communities. This is especially true in the rural and mountain towns of the state, where recreational activity is both a major economic driver and central player in the making of everyday life.

Take, for example, the town of Steamboat Springs, located in Routt County. Just past the Continental Divide as one moves toward the northwestern corner of the state, it is home to the lion's share of Routt County's 20,000 or so inhabitants, and is built around welcoming visitors to their eponymous hot springs, local ski slopes, river courses, and surrounding public lands, with over a third of the jobs in the town and surrounding county coming from tourism-related industries.³² Surrounding farms, while generally able to access regional and international markets, are nevertheless often tied closely to the local tourism economy in the area, as they sell to local establishments, draw from common labor pools of seasonal workers, and may, themselves, be involved in some form of recreational business. Similarly, specialized hunting guides, fishing guides, river guides, general outdoor outfitters, event coordinators, and a variety of local retail outlets all derive significant benefits from the attraction of the nearby ski slopes and other natural amenities, and these industries often absorb a portion of the ski resort labor force during the off season as well.³³

Because of this, effects from drought and other weather conditions on one industry often have ripple effects in others, and particularly dry years - like 2018 - can result in multiple different types of recreational businesses facing challenges simultaneously. As below average 2017 snowfall gave way to deepening drought conditions over the rapidly warming summer, water in streams for agriculture and various

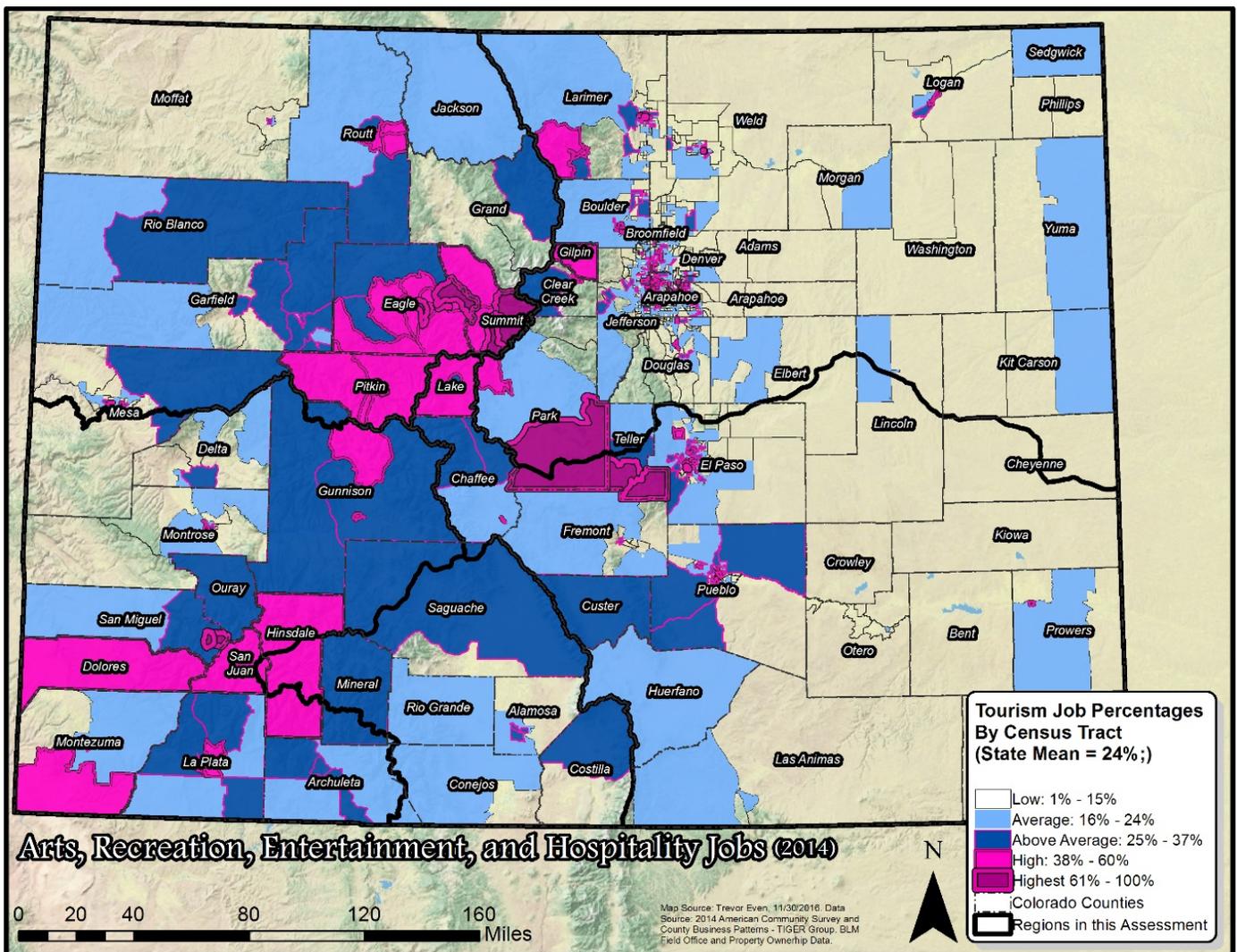
Silverton, San Juan County, and the 416 Fire

Tucked into a high elevation mountain valley just north of Durango, the former mining camp of Silverton lives and breathes on the state's local and international tourism economy. With around 600 permanent residents, nearly all economic activity in the town and surrounding county reliant upon tourism in some way, with over 60% of all jobs in the county in tourism related sectors. Small even by the standards of many mountain towns in Colorado, it relies heavily on the nearby national forests (88.7% of San Juan County is federally managed land), high intensity ski operations, and the Durango-Silverton Narrow Gauge Railroad, a working recreation of 19th century transport during the area's initial mining boom that ferries passenger to the town's center to shop in the various boutiques, galleries, and gift stores that make up most of the town's main street.

This year, however, has seen significant disruption to the year's normal rhythm as a result of the nearby 416 and other fires, whose smoke and resultant forest closures - as well as the closure of the Durango-Silverton railroad - meant that many local business owners were left little to show for what is normally their busiest part of the year. As one local store owner put it, speaking to the Durango Herald in June, "*It's hard on the locals. We work hard for five or six months so we can live off our own money for the winter. So, yes, I am a little worried.*" Others in town were equally concerned, with some celebrating days where sales approached 50% of normal, and others finding solace in having under-purchased inventory (Armijo 2018a). Total impacts from this summer's drought driven wildfire season aren't clear - nor is it clear whether snow packs will recover in the coming winter season. However, local estimates of total sales losses range from 15-30% of normal.³⁵

recreational resources began to run dry, eventually forcing closures on the nearby Yampa River for fishing, a shortened rafting season, and - for the first time in history - a call on nearly the entirety of the river itself that reached water rights holders as senior as Sept. 16, 1951.³⁴ As of late November, when hunting season begins to move into full swing, restrictions remained in place in much of the surrounding region for campfires and other high fire-risk activities.³⁵

What effects these challenges will have on the overall economy of Steamboat Springs and the surrounding area is unclear. The state's recreational economy overall has been growing rapidly after rebounding from declines during the last economic downturn 10 years ago, and remains strong due to both rising demand, artificial snow-making at most ski resorts, and the wide availability of alternative attractions when specific activities are not available.³⁶ However, statistics gathered following the 2012 drought suggest the likelihood of reduced visitation numbers across all recreation industries, with river rafting and skiing in particular showing significant declines in visitation during the high-fire risk, low water conditions of that event.³⁷ Similarly, reports of impacts from drought and associated wildfires have suggested that a broad range of negative effects on the recreational economy can be



Map 11 - In many areas of Colorado, tourism-related economic activity is the only game in town - i.e., the only option for jobs, and likewise, the main reason for living in a given town in the first place. However, these areas face significant risks when tourism spending declines, or local extreme weather events send visitors elsewhere.

expected, whether from near-statewide delays to the start of the 2017 ski season; river closures along the Roaring Fork Valley; dry riverbeds in Eagle County; water levels too low for rafting in parts of the Uncompahgre Basin, Glenwood Canyon and other areas; extreme low snow levels in Crested Butte and other medium sized ski resort areas; dry waterfalls and failed mushroom harvests near Telluride, or various closures of federal lands due to the state's numerous wildfires.³⁸

More importantly, it is very likely that much of these impacts will not be borne equally by all members of the recreation and tourism industry. While large, well-resourced resorts like Vail and Aspen may have the capital and diverse array of attractions needed to meet whatever demand the global economy provides, smaller, more specialized businesses like part-time hunting guides or rafting guides that



Photo 7 - Pine trees killed by beetles. Credit: USDA NRCS 2015.

work only specific rivers are likely to face sharp increases in the cost of doing business at the same time as opportunities for access shrink.³⁹ Simultaneously, towns further off the beaten path, such as Craig, Ouray, Walden, Gunnison, Kremmling, Salida, and others scattered around the state may lack the resources or non-tourism related income streams needed to keep businesses open during particularly rough years. Similarly, in communities where reliance upon the tourism economy is extremely high, such as is seen in parts of Eagle, Clear Creek, Chaffee, Fremont, western El Paso, and various other counties, the effects of a downturn can be devastating, even over short periods. As a result, while the tourism-based economy of the state as a whole may march on, relatively heedless of direct weather impacts, specific communities with limited resilience may face significant setbacks and a loss of the ability to meet basic needs.

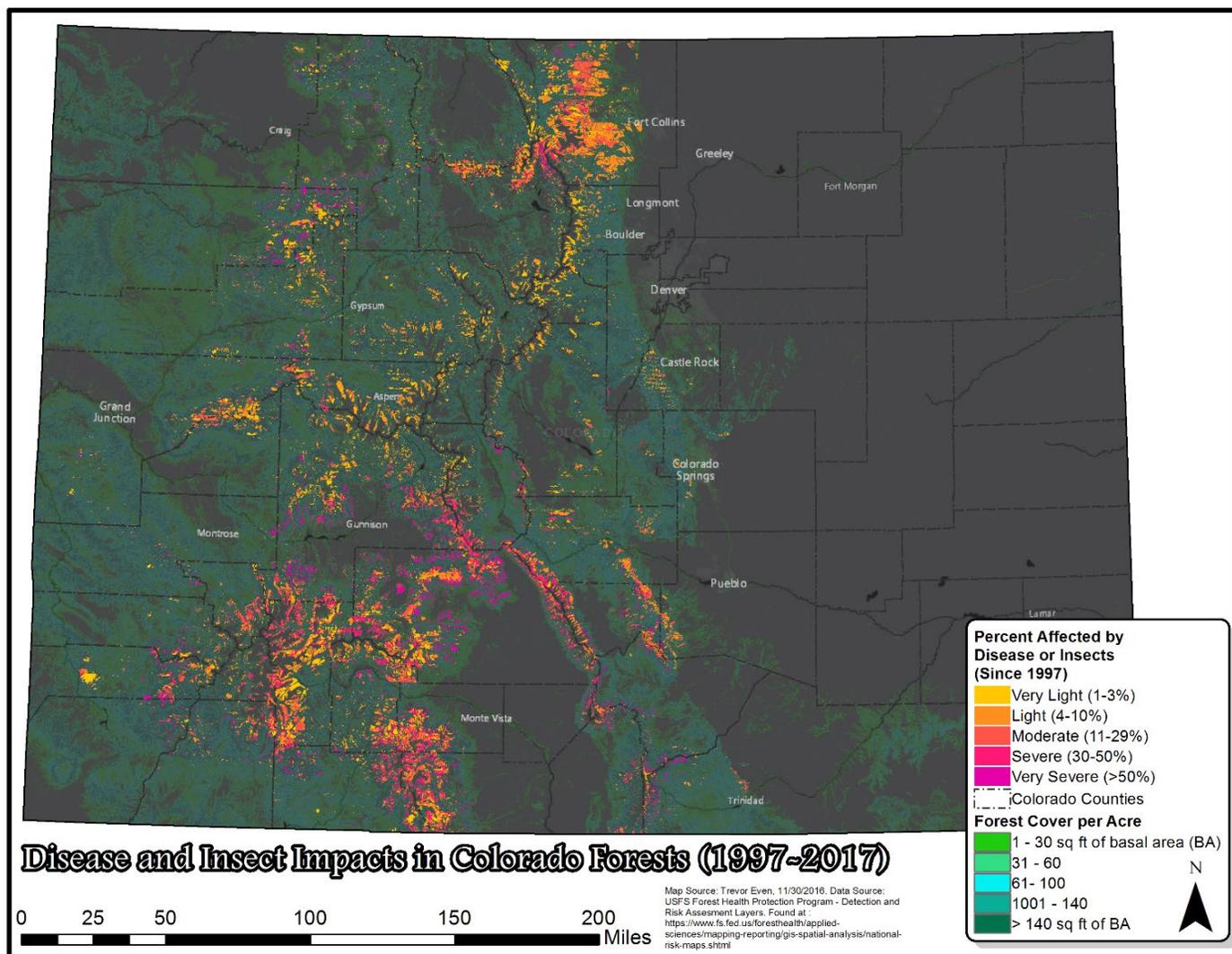
These short-term shocks have come alongside growing concern across the outdoor recreation community regarding what higher temperatures, changing seasonal timing, and other more long-term shifts to the area's weather patterns mean for the industry. In the skiing industry, this has meant the large-scale adoption of snow-making technology, which utilizes water stored in reservoirs and electricity to generate artificial snow when natural precipitation fails (or falls as rain). However, these rely upon water reserves that are themselves subject to the state's prior appropriation system for governing water diversions, meaning that successive years of drought like those experienced in 2002, 2012, or 2018 could defeat even the most efficient snow-making efforts. As a representative from the Colorado Association of

Ski Towns noted when speaking with researchers on this project, unpredictability in the start of the ski season can also have more complex impacts, such as those seen during the early 2017 season, when delayed starting dates at most resorts meant that ski towns had to find resources for the large influx of seasonal workers who, as a result of these delays, found themselves in a generally very expensive place to live with no means of earning an income. As a result, the social service resources of the surrounding towns and counties - be they food banks, heating assistance programs, rent subsidies, or job placement resources - found themselves suddenly stretched to the brink.⁴⁰ Similarly, as winters in the mountains become more mild and the weather becomes overall warmer, many mountain towns face the double edged sword of increasing real estate development and settlement by (generally high-income) retirees. While this type of influx can be beneficial to local tourism-dependent communities, it can also cause significant rises in housing prices in areas with limited land suitable for development, forcing lower-income workers to either seek alternative places to live, migrate elsewhere, or take part in development that further erodes the wildland-development interface.

Similar long-term effects of warming weather and shorter winters can be seen in the state's iconic forest ecosystems, which contribute both directly and indirectly to the overall appeal of Colorado tourism destinations. Acting as a sort of living infrastructure for ski resorts, mountain water utilities, and as habitat for wildlife critical to a broad host of recreational activity, the state's forests are undergoing rapid transformation. Some of this is due, of course, to the many high profile and historically enormous fires that have burnt in the decade or so. Most of the transformation, however, comes in the form of insect and drought driven mortality in Spruce, Ponderosa, Douglass and other evergreen tree species found surrounding nearly every community in the western half of the state. According to a recent report by the Colorado State Forest Service, over 5 million acres of forest statewide have been affected by just Mountain Pine Beetle and Spruce Beetle alone since 1996, with roughly a half million more affected by other, less pervasive species. Driven in part by decades of fire suppression that left forests particularly vulnerable, these insect and disease related impacts have also been noted to be greatly assisted by the lengthening of the frost free season, which allows insects to reproduce more effectively and overwhelm most tree species' natural defenses.⁴¹ The result is that many mountain town resorts look out upon forests that are up to 50% dead and mostly standing trees in the surrounding mountainsides, with serious implications for forest management, wildfire risk, and the intangible aesthetic values of a given community.

In river-related industries, the increasingly rapid onset of spring and subsequent intense runoff that has been characteristic of much of the last two decades has meant the need to find new ways to provide both safe access and to cope with unpredictable resources (see next Section). In rafting, this has come as a result mainly of the amplification and shortening of the rafting season in many headwaters areas, which result in less time for the specific conditions that different types of rafters seek.⁴² In some cases, because of either high flows that make rivers too dangerous to attempt, or low flows that prohibit boating altogether, business simply does not occur. For some operations, it has also meant expending more energy and travel time as they must seek out alternate courses during localized severe drought conditions.

Fishing guides and outfitters for self-guided fisherman have also begun to voice serious concern regarding the impact of warmer temperatures, shorter winters, and incessant drought conditions, as these can all have significant impacts on the health and abundance of numerous important native and stocked fish species. The most basic of these effects come, as they have this year, from stream levels depleted by drought and upstream diversion to levels too low to support fish populations.⁴³ For some species like the rainbow and cutthroat trout, however, warming water temperatures associated with these low flows presents as much a problem as low flow levels themselves, as they put the fish under enormous stress and can quickly lead to fatality. Even when catch and release restrictions are in place, catching fish at all can prove deadly if water temperatures rise above the mid-sixties in some species.⁴⁴ The result of these poor fishing conditions has led to a variety of voluntary and non-voluntary closures of rivers to fishing and other activity. However, over the long term, there is concern that the loss of cold-water fish habitat will be permanent if higher temperature



Map 12 - Insect and disease mortality of trees in Colorado's forests are just one sign of changing weather patterns, with longer, warmer winters playing a central role in allowing pests to spread and reproduce more rapidly. At the same time, forest management has also played a role in heightening the virulence of these issues, with many forests in need of significant restoration.



Photo 8 - Dream Lake, found in Rocky Mountain National Park. Beetle killed pine are reddish trees visible at right. Credit: Sean Corrigan, 2016.

trends continue. Similarly, drought conditions and associated wildfire can also have serious impacts on fish populations and river conditions, as post-fire landscapes allow for rapid erosion, and often transport large amounts of debris and ash into nearby streams. In these cases, the chemistry of the water itself can be altered to such a degree that fish die off in huge numbers, both near to the fire and far downstream.⁴⁵ In 2018, this has resulted in Colorado Parks and Wildlife and a variety of volunteer organizations working to rescue fish from the Animas River and other streams heavily affected by post-wildfire runoff-induced toxicity as die-offs mount in many prized fishing areas.⁴⁶

Impacts on hunting over the last two decades have been more mixed than in other sectors, mainly due to the extreme adaptiveness of both hunters and the hunted, respectively: in many cases, short term drought conditions can actually improve the likelihood of the success of a given hunt, as wildlife congregate on smaller areas of water and remaining vegetation. Similarly, most hunted wildlife species - which include elk, mule deer, whitetail deer, brown bear, mountain lion, and numerous others - are able to mitigate the impacts of locally poor forage or water availability through movement. However, longer term changes to the landscape and the weather may prove more than most hunting species can handle. For example, droughts that last for a year or more can lead to subsequent “forage droughts” for species like white tailed deer, mule deer, elk, and antelope, which make up for much of the state’s hunting activity. In 2002, for example, when much of the state was in severe or extreme drought, Colorado Parks and Wildlife increased cow elk licenses in an attempt to mitigate impacts on already threadbare forage, in hopes that it would allow those elk that remain to better weather the coming winter. At the same time, bear licenses were decreased in response to field reports of poor female bear body condition entering the hibernation season.⁴⁷ Early springs that are followed by late season frost might also present challenges to wildlife, as it can lead to both the loss of animals directly and the reduction of fruiting bodies on shrubs and trees.⁴⁸ However, severe winter storms that occur during the normal time frame can also affect hunting, for while they are generally welcomed in the area for the moisture they bring, they can result in significantly increased mortality if herds are unable to move out of high elevation browsing grounds in time.⁴⁹ That said, both of these types of pressures also come at a time of rapid population growth and development in many areas across the state, meaning that impacts from weather are heightened as herds are pushed into

smaller and smaller areas, potentially increasing their risk of disease at the same time as their access to resources is reduced.⁵⁰

Changes to the onset and character of winter can also create complications for planning hunting trips - and for hunting guides, ensuring success - as migratory species like elk and deer generally follow the weather, rather than the Colorado Park's and Wildlife's permit schedule. As one outfitter operating out of Maybell told *Guidefitter* magazine in 2017, *"In their normal migration pattern, they'll start out in late October or so and they'll move to the mid-section on the mountain. They'll hold there for awhile and then as the weather progress they'll start moving on down to the lower winter ground. The last few years here, I don't know it's been because of drought conditions that we've been having, but they've come down a lot later."*⁵¹ This year, the Colorado State Extension service is already issuing warning of degraded habitat conditions for most wildlife species, as well as increased risks of wildlife-related vehicle accidents as ungulates take to browsing on the green bands that normal form in drainage ditches.⁵² Reports from hunters from various sources have noted that, in addition to poor body condition, drought years (or even poor forage years) such as these can have serious effects on bull elk maturation and can result in poor antler formation.

These more gradual impacts in various specific industries all share several aspects in common: when water is scarce, more effort must be undertaken to utilize what remains, getting to it might be cost-prohibitive, and what remains can lead to competition. Likewise, risks increase that visitors - or merely those attempting to enjoy a private hunting, skiing, fishing, or boating trip - will be faced with conditions that are either dangerous or simply not worth the journey. For ski resorts and other mountain towns that rely on providing a wide array of recreational activities, wildfires, whether nearby or at a safe distance, cause serious negative impacts as tourists shy away from the visible hazard these events represent - and may well cause direct damage to resources that local communities rely upon as part of their business strategy. Moreover, as pressure from human communities increases apace with pressures from shifting weather patterns, the species and ecosystems that make the state so spectacular and memorable are also at risk of losing the capacity to cope with weather extremes. As with ranching and agriculture, the conditions presented to Coloradoans by the 21st century are causing a variety of changes in how the state's tourism economy survives, and where it sees itself going in the future. In the next section, we will explore some of the pathways that have been laid out.

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Photo 9 - Silverton, Colorado. Population: Approximately 650. Credit: Mike McBey (Flickr.com), 2013.

Adaptation and Innovation in Rural and Mountain Communities

Given the wide range of risks they face - as well as the seriousness of the impacts from weather related disasters that the last 20 years have already brought to bear - it is becoming increasingly clear that rural and mountain communities in Colorado must engage in a new phase of adaptation. For communities that rely upon ranching, farming, and the diverse landscapes that define our state, the future seems to put forth a simple, if daunting challenge: either adapt, or face the consequences. Granted, for anyone who has spent even a little time making their living off of the land, this is hardly a new challenge. The true question, then, is whether or not the ingenuity and determination that have served Coloradoans in the past will prove up to the task of facing down the new challenges presented by changing weather in the 21st century. According to the global scientific community, much of the road ahead remains profoundly uncertain, and will rely upon technological, social, and political transformations taking place from local to the global scales. For ranchers, farmers, and businesses that rely upon the natural environment in Colorado, however, what these changes mean on the ground will depend upon every scrap of creativity, determination, and innovation that we as a statewide community can muster. Luckily, Colorado is no stranger to change, and in many ways, its historically challenging and diverse climate has prepared us - perhaps better than most - to marshal the will needed to chart a new path forward.

Indeed, as is often the case in land-based livelihoods around the world, practitioners across the state are already taking steps to strengthen their operations against the rising challenges of weather-related disasters and extreme variability. In some cases, these innovations are purely technological, relying upon newly discovered methods for understanding the weather, crops, and the broader environment to maximize operational viability. In others, they rely upon changing practices, ranging from new ways of looking at the role of soil in agriculture to novel approaches to promoting and protecting the economies mountain tourist destination. In still others, communities are returning to time-tested principles of collaboration and communication to face down otherwise insurmountable resource challenges.

In this section, we attempt to collect just a small handful of these newly emerging - and, in some cases, newly rediscovered - approaches to ensuring the viability of rural livelihoods, both with a mind to share insights from those working on the ground to implement these practices, and to inform those in a position to set policy and make wide-ranging decisions about options already available. For while it is likely that the most important changes to practices will take place due to the independent action of farmers, ranchers, recreators, and other rural economic actors, it is also clear that even the most clever adaptations will require the support of decision-makers at all levels of authority, be they municipal leaders, state lawmakers, non-profit organizations, or our representatives within the federal government. In order for this support to be effective, however, it is critical that decision-makers - whatever their standpoint - are informed about action already taking place on the ground. To do so in a straightforward manner, we address specific adaptations in terms of the specific sectors to which they apply. However, as what follows will show, many of the strategies and approaches described here have surprising parallels, both in terms of the specific approaches applied, and in the change in perspective required for dealing with times of increasing variability and extremes.

Ranching

Dealing with harsh weather conditions is a normal part of keeping livestock, and as a result Colorado's ranchers are apt to use just about any tool that makes sense for their continued operation. As a result, a number of types of adaptation and innovation in the ranching sector are already underway, both in direct confrontation of weather-related risks and due to the overall uncertainty of the ranching sector in a globalized economy. These range from technological approaches to maximizing productivity to radical diversification of rangeland utilization and dramatic changes in traditional models of ranch operations. In this section, we cover but a small slice of statewide adaptation activity.

The most important of these come in the form of efforts to manage water. Although exact statistics are not available, it is generally well known that ranches in Colorado heavily upon groundwater withdrawal, particularly in the eastern plains where surface water availability is confined to a few major streams and seasonally flowing creeks. Traditionally, this was accomplished with first wooden and then steel windmills attached to basic pumps, which would then fill accompanying above ground tanks or artificial ponds. In many places, this form of water management persists, and has proven a cost effective means of providing water for livestock across the entirety of a given ranch's range. Now, however, windmills are



Photo 10 - Ranch near Hayden, CO. Credit: Rdg01 (Wikimedia.org) 2018.

often accompanied by electrically powered pumps and pipeline systems, that allow for single wells to distribute water across a broad area. In some areas, ranchers are creating “intelligent” well control systems that allow them to turn on and off specific tanks of water remotely, and by doing so, effectively moving cattle across the range automatically in areas where pumped water is the only available resource. Water can also be hauled in tanks using trucks, although this is generally viewed as both costly and onerous.

However, water for livestock is only one part of the equation: management of the vegetation and overall landscapes that livestock rely upon for the vast majority of their food is just as critical. With more frequent drought putting many rangelands in a more fragile state, ranchers have had to take a variety of measures to ensure the long-term sustainability of their operations. The most basic of these involves simply reducing the amount of range needed, either through purchasing supplemental forage, or growing one’s own feed in the form of irrigated or dryland alfalfa. When these reserves prove insufficient - or too costly - ranchers may also sell off a portion of their herds. Unfortunately, when drought occurs, demand for supplemental feed spikes, and likewise, the glut of cattle and other livestock on the market drives prices per head downward. In particularly bad droughts, alfalfa and hay crops might also fail if they do not receive enough irrigation or rainfall, further heightening impacts. Because of this, managing rangelands during drought episode is an area of significant research, both academic and otherwise, as reactive measures like those listed above can only work for so long before costs become overwhelming.

For some ranchers, this has meant taking a more drastic approach to the usual practice of moving herds from one pasture to the next. In southeastern Colorado, for example, numerous ranchers have begun loading their cattle onto trucks following the early corn and wheat harvest in Kansas, Oklahoma, and Nebraska, and trucking them there to graze on the remnants. Others - specifically, the more prosperous ranches with the ample resources needed to do so - have taken a different approach, in which smaller properties are purchased in a spread-out manner (sometimes over distances of hundreds of miles), allowing for the ability to take advantage of diverse local conditions in times when one area is under stress. This has followed alongside a general recognition in many ranching communities that many working rangelands are seeing consolidation - or the formation of especially large ranches as others close and are bought out - in many areas, notably southeastern Colorado where land values have remained relatively low despite rising prices elsewhere in the state. Simply put, having more access to land provides flexibility in decision-making on every level of ranch operations. However, whether in purchase prices, leases, or transportation fees, all

of these strategies bear significant costs, meaning that they are generally more useful for solidifying an already strong position than recovering from a poor one.

One strategy being widely utilized by Colorado ranchers to deal with the numerous uncertainties involved in ranching (weather-related or otherwise) is to *diversify*. For some, this means simply taking on additional, non-ranch work in nearby towns or with other local businesses.¹ In other cases, this means the diversification of the ranch itself, usually through the addition of business models other than livestock production to an overall portfolio of land utilization and stewardship. For example, many ranchers in northwestern Colorado are involved in some way or another in the local hunting economy, either through hunts conducted on their own land or through hunting guide businesses.² Other, perhaps more extreme examples include: the James Ranch, located near Durango, which, in addition to a grass-fed beef operation, also produces chicken, pork, cheese, vegetables, and other products alongside an active environmental education tourism destination, farm-to-table restaurant, and special event facilities.³ Similarly, Sylvan Dale ranch, located in the mountains just west of Loveland, also produces grass-fed beef as the central component of a full-scale recreational resort model featuring wedding and other even facilities, guest cabins, equestrian training, and other recreational activity.⁴

At the same time, a number of ranches of varying size across the state are taking on new strategies not just for how their ranches are organized financially and across space, but how they approach the management of the various natural systems that make up the ranch itself. Although these methods go by various names, including holistic ranching, ranching for ecosystem services, ecological ranching, conservation ranching, ranching for wildlife, ranching for soil health, or simply, intensive (or *extensive*) rotational grazing, these new approaches to running a ranch are united in the basic idea that landscapes and ecosystems



Photo 11 - Wild and domesticated horses at a ranch near the Colorado/Wyoming border. Credit: Carol M. Highsmith (Library of Congress; Rawpixel Ltd.), 2018 version.

Ranching for the Future in Northwest Colorado: L_____ Ranch and V_____ Sheep Company

Two standout examples of how taking a holistic approach to rangeland and ecosystem management in Colorado, Ladder Ranch and V_____ Sheep Company represent how private land owners operating at the interface between wildlife dominated landscapes and federally managed lands can sustain ranching livelihoods through novel approaches to understanding the environments that livestock depend upon.

At Ladder Ranch, located on the Wyoming-Colorado border just north of Steamboat Springs, 2014 Leopold Conservation award winner P__ O'T_____ works as a 4th generation rancher to maximize sheep and cattle productivity in the midst of a living landscape, organizing his fencing, rotation, and supplementary feeding practices to allow for abundant wildlife habitat, riparian ecosystem restoration, and the preservation of the surrounding landscape for future generations. With both he, his wife, and various other family members being extremely active voices in the Colorado and Wyoming agricultural communities - as well as avid partners with environmental and agricultural non-profit organizations - they also work to make sure that the issues of rural America remain at the forefront in discussions of resource governance and use across the arid west. In so doing, he has managed to maintain the viability of future generations of the O'T_____ family to maintain ties to the ranching way of life, and to ensure that the mosaic of private and public lands he manages are sustained for future generations to learn from and enjoy.

Just southwest of L_____ Ranch, in Moffat County, the V_____ Sheep Company utilizes a variety of environmentally-minded and ecosystem-centered approaches to ranching to ensure that the mix of public and private lands they utilize are able to maintain productivity and vitality both for their own business interests and those of the broader hunting, fishing, and outdoor recreation economy. Utilized a “forage-based” range management approach, in which the soils, plants, and wildlife of the range are viewed as the central component of successful ranching operations, they have been able to achieve remarkable conservation and ecosystem restoration goals in what have been historically viewed as arid wastelands. Also a Leopold Conservation awardee, the V_____s are also active participants in the Colorado Parks and Wildlife Habitat Restoration Program, and host a variety of hunters and anglers from around the world each year. As Gary V_____, the current ranch manager told the Sand Creek County Foundation in 2013, *“I love the land, I love seeing the wildlife, and I love the livestock as well. I can't imagine a universe without it all there - it would be boring. When you love the land, you don't destroy it, you want the next generation to be here, and to be able to see what I've been able to enjoy.”*⁸

take a central role in the planning, implementation, and evaluation of overall ranch goals. As a result, the measurement of a given ranch's success comes from evaluating both the health and quality of cattle sold and the resilience of the various plants, animals, and soil biology surrounding them.

Or as Grady Grissom, an ecologically-focused rancher operating out of southeastern Colorado put it in 2017: *“Ranchers are not outside the ecosystem managing it; they're in the ecosystem, trying to survive.”*⁵ As a case study on his family's ranch, published in the journal *Rangelands* in collaboration with researchers from Texas A&M noted, this style of ranching requires intense focus on developing and implementing the variety of monitoring and ecosystem management tools needed to meet specific ecological goals. This includes changes to the distribution and style of fencing (i.e., using temporary electrical fences to make shifting pastures less labor intensive), making time for the monitoring of various rangeland vegetation and wildlife species, forging connections with ecologists and other scientists to assist in understanding the ecosystem process at play within the ranch, and

consistent adaptive planning efforts that allow for the ranch to pro-actively address issues like drought by controlling stocking rates *before* rangelands become overly affected.⁶ Another important part of this approach is changing how ranchers understand and interact with soil systems, both in terms of their cycling of minerals through the planting and grazing of specific species, and with regards to how these planting and grazing decisions alter how soils absorb, store, and redirect water across the landscape. Because of this, there is significant evidence to suggest that, by cultivating the surrounding ecosystem for resilience with the same tenacity with which most ranchers attempt to maximize stocking rates and livestock weight gain, they are able to create a landscape that is both able to support the Grissom family’s livelihood and to absorb the shocks of extreme weather events and variability.

Indeed, one broadly applicable theme to emerge from research on ranching in this region is that the idea of *land stewardship* is highly consistent across the state. Although individuals vary, the basic concept that lands used for ranching are environments that should be *stewarded*, managed, kept whole, and preserved for future generations is commonly encountered, even among those who oppose the imposition of federal regulations such as the Endangered Species Act or other forms of outsider “environmentalism”. Because of this, several notable programs exist that either assist or compensate ranchers in efforts to operate rangelands for reasons other than livestock production, exclusively. The largest and most notable is perhaps the Colorado Parks and Wildlife [CPW] Ranching for Wildlife, which has been in operation since 1986. Putting it simply, this program creates partnerships between large private ranches (12,000 acres or more) and CPW to provide access to privately owned hunting grounds. In exchange for a portion of the fees from hunting licenses, ranchers agree to develop and implement plans for wildlife habitat restoration on their properties. Currently, 27 ranches are enrolled in the program, opening access and improving conservation values

Innovation on the Science-Agriculture Frontier:
Community-driven Agricultural Research in Colorado

In addition to a wealth of innovative approaches to running ranches and farms, Colorado is also blessed with an academic and scientific community world-renowned for its dedication to changing the way that scientists and other experts interact with on-the-ground practitioners. Notable among this community is the work of Justin Derner and various collaborators at the USDA Agricultural Resource Research Service and Climate Hub, whose work focuses on partnering with ranchers and farmers to develop real world experiments aimed at better understanding how landscape conservation, agricultural production, and western ways of life can achieve their goals in synergistic ways. A vocal advocate for soil- and ecosystem-centered approaches to agricultural production, his current work aims to develop a wide ranging network of active experimental farms and ranches where researchers from around the world can collaborate with local agricultural producers to develop innovative practices and maintain the sustainability of the world’s food system for future generations.

Another notable figure in the Colorado land-based livelihoods research community is Maria Fernandez-Giminez, whose work out of Colorado State University aims to put ranchers and farmers in western Colorado at the center of efforts to understand pressing dilemmas in the management of rangelands and public land resources. Using a community-based, participatory approach, she combines social and ecosystem science methods to explore how local values and environments interact with global markets and weather-related impacts, and how lessons learned therein can be utilized to ensure that future generations can both utilize and enjoy working rangelands around the world.

to over 121,000 acres of private land that might otherwise be subdivided and sold or more intensively grazed.⁷ By siting these partnerships strategically, CPW has also managed to maintain numerous important wildlife corridors between large private ranches and public lands. As a result, in addition to diversifying their sources of income, these ranchers are also able to help create larger, interconnected landscapes that support a variety of other livelihoods and cultural activity in the region and may potentially provide a buffer for highly valued wildlife in times of drought or other stress.



Photo 12 - Supercell storm brews behind a windmill, somewhere near Springfield, CO. Credit: Kelley Delay (Flickr), 2012.

Efforts by ranchers to maintain healthy landscapes as a means to contend with drought and other weather challenges can also be found in a number of non-profit and ranching organization award programs active in the state, which provide both recognition and various monetary awards to ranchers who demonstrate innovative and environmentally beneficial land stewardship practices. The Aldo Leopold Conservation Award, supported by the Sand Creek Foundation and various state Cattleman's Associations across the west, for example, has highlighted multiple Colorado ranchers who have successfully engaged with conservation and ecosystem rehabilitation efforts, often due to a change in land management after significant weather-related impacts revealed vulnerability in old models. The 2011 award winners, the McEndree family and Pipe Springs Ranch, demonstrate this well. Operating out of the extremely arid and highly variable area around Springfield (in the far southeast corner of the state), they emphasize how land conservation strategies have served as a ranch resilience builder. Due in part to the much more dynamic grazing model utilized in their rapid rotational scheme, as well as a focus on the relationship between water, soils, and diverse plant communities has allowed their ranch to achieve continued growth despite the region's intense exposure to extreme drought conditions over the last 20 years. As the McEndree family puts it, "*Focusing on conservation has allowed the land to flourish even when Mother Nature has not cooperated.*"⁸

Significant experimentation and research remains to be done in the arena of ecosystems-informed ranching (and various derivations thereof), both in terms of its ability to improve the lives of ranchers, and in its capacity to produce more resilient natural landscapes. However, because any process of adaptation requires that those doing the adapting must learn from the systems they are adapting to, the heightened awareness of environmental characteristics and response patterns that comes with these new types of ranching strategies appears quite promising, both as a means of further adjusting to weather-related impacts as well as learning what different environmental conditions mean for rural livelihoods more broadly.

Farming

Maintaining the viability of the agricultural sector in the face of weather- and pest-related hazards is the focus of numerous multi-billion dollar corporations, millions of scientists and researchers worldwide, and, in the United States, is the target of a variety of subsidies, insurance programs, and other federally supported resources for education and operation improvement. Colorado farmers, like farmers across the country, are therefore limited mainly by personal capital, on-farm flexibility, local access to non-financial resources, and the demands of global markets when it comes to integrating new technologies and practices into their operations. Weather-related losses have been a part of agriculture since its invention over 13,000 years ago, however, and still remain a relatively absolute force in the lives of farmers: If you farm, you must accept and plan for the possibility of weather-related losses, no matter how optimized your farm might otherwise be in terms of maximizing the production of calories per unit of water and land available. Given the vast size of many modern farms in the state and their reliance on large plots of single or homogeneous crops, they are inherently vulnerable to wide-scale issues like hail, drought, tornadoes, insects, mold, and other insults to plant productive processes. To survive in the face of such challenges, farmers have traditionally relied upon savings, alternate crops, emergency planning, and, ever more increasingly, federally-subsidized and private insurance plans. That said, a number of Colorado farmers are undertaking efforts to move beyond the incremental technological and genetic improvements that have characterized much of the development of modern, industrialized farming, be it in terms of how they plan, plant, and manage crops, how they integrate farming into overall livelihood strategies, or how they operate within local markets. In this section, we will cover a few of the more notable and potentially expanded upon innovations that have taken root in Colorado, as well as some of the broader context that shapes adaptation decision making (at times in somewhat counter-intuitive ways).

Although non-irrigated, “dryland” agriculture is a critical part of the state’s overall crop production, the generally semi-arid conditions found in most of the areas suitable for agriculture in the state require farmers to irrigate their crops. This is accomplished in two main ways: either by flood irrigation, in which waters pumped or directly diverted from surface streams are allowed to completely inundate the root zone of crops and saturate soils at critical growth stages, or through the use of sprinklers, most commonly seen on center-pivot armatures that allow a single pump to provide water for an entire field. A third type of irrigation, known as drip irrigation or “microirrigation”, is also used to a much smaller degree, and utilizes tubes laid on or just below the soil surface to deliver precise amounts of water to each plant individually. In terms of absolute water use efficiency, flood irrigation is the least efficient, with up to 50% of diverted water being lost to surface runoff, or “tail” water. Sprinkler irrigation is more efficient, with losses to wind, evaporation, and deep percolation ranging between 10-40%; drip systems, on the other hand, are even more efficient, with up to 90% of water applied arriving and staying in the target plant’s root zone.⁹ However, costs in terms of initial installation, maintenance, and additional work during harvesting may be higher in more efficient systems. Though there are ongoing discussions regarding the building of additional

water storage facilities, or developing a system for re-utilization of processed water from cities, these options have yet to be realized, and face significant uncertainty.

As such, if one were planning a hypothetical farm, then it would simply be a matter of cost comparison between different irrigation approaches based on the cost of water and the desired production outcomes. However, in the real world, farms must deal with decisions made by those who came before them, and must deal with the specific soils and topography that they already have access to. Because of this, changes to patterns in irrigation systems and other farming practices are generally slow to occur, as the investments made by previous generations of farmers often make large scale alterations generally too costly or inconvenient to implement, even if financial gains could be made over the long term. More importantly,

Community Leadership for Agricultural Resilience: The Community Agriculture Alliance

Colorado's ranching and farming communities have proven highly capable in organizing at a variety of levels to support the viability of their livelihoods, especially at the local and regional level. One example of these efforts comes in the form of the Community Agriculture Alliance, operating out of Steamboat Springs. Led for the last 15 years by Marsha D _____, a Routt County rancher and feed farmer, it engages with local and regional communities on a variety of fronts to ensure the sustainability and viability of Routt County agricultural operations. This includes organizing community events and farmers markets to promote local agricultural producers, educational programs for non-farmers and new farmers, and county-level lobbying on a variety of issues. For example, in the last several years, the CAA has sought new ways to partner with recreational businesses and other local institutions to ease conflicts between newcomers to the region and the agricultural community over issues like bicycle traffic, land access, and trail development. Noting both the need for a new generation of farmers as well as the rising prices of agricultural land, they have worked to improve the efficiency of permitting and other processes related to establishing greenhouses and other "micro-farming" establishments that aim to serve the area's local restaurants, and allow a new generation of agricultural producers to enter the field. They also currently operate an on-line farmer's market, bringing locally produced farm products, vegetables, and beef. Although she is now retired from her position as CAA Executive Director, D _____ continues to advocate for efforts to improve the resilience and well-being of Yampa Valley farmers and ranchers. In conversations with project researchers this summer, she noted four key areas where work remains to be done in terms of improving the agricultural community's ability to deal with extreme weather and change:

- 1) There is a need continued support and expansion of programs to provide farmers and ranchers with accurate information on weather risks and management practices that allow for adaptive responses. This also includes better support for general agricultural education programs and mechanisms to support new farmers.
- 2) Find ways to improve funding security and capacity for extension agents, especially local USDA staff that provide a critical conduit of scientific information and practical innovations to rural agricultural operations.
- 3) Improving coordination between Federal, State of Colorado, and county officials, as well as between the U.S. Forest Service and the Bureau of Land Management, which oversee public lands used for cattle ranching and recreation.
- 4) Finding ways to insure against or expand coverage under existing aid programs for multi-disaster years, such as when drought is followed by serious hail damage, as these remain a serious threat to farm viability.

because Colorado is a state whose water rights system values a given diversion right on the basis of the water actually used by a given crop, switching from one irrigation system to another also requires some degree of interaction with the State Water Engineer and water right adjudication system, i.e., the Colorado Supreme Court, as new water use, loss, and groundwater interaction values will have to be determined and affirmed by the various parties involved, including any downstream parties that might be affected.¹⁰

Because of all this - namely, the very real tradeoffs between water use efficiency and operational costs, as well as the tangled process of changing irrigation methods while maintaining the entirety of a given (increasingly valuable) water right - simply pursuing more efficient methods of agricultural water use are not always the best option for farmers in the state, even as continued droughts put the predictability of water supplies in serious question. More importantly, because of the way in which the state's laws handle water shortages, wherein rights holders with junior rights are subject to the demands of those with more senior appropriation dates, the ability to acquire necessary water for irrigation or other uses can become less a matter of applied hydrology and engineering than one of careful negotiation between the various parties involved in a given reach of stream or aquifer. For example, as research in the Yampa-White Basin examining the impacts of the 2002 drought found, social capital in the form of trust, communication channels, shared goals, and the ability to cooperate in times of scarcity can prove just as important as the ability to construct dams, floodgates, and other infrastructure. In that case, community members from the agricultural, recreational, municipal, and industrial sectors in Moffat, Routt, and Rio Blanco counties enlisted a variety of informal mechanisms (such as meetings and town halls) to address extreme drought conditions in the region, doing so in a manner that allowed for the Yampa River, junior irrigators, and the small town of Craig - which faced potential water shortages due to downstream senior rights - to receive reduced water allocations without the need for official legal calls that might have otherwise devastated the local economy.¹¹

One particularly profound example of people working together to solve region-wide water management problems can be found the San Luis Valley in south-central Colorado,



Photo 13 - Groundwater-fed center-pivot irrigation in the San Luis Valley. Credit: Doc Searls (Flickr.com), 2008.

where farmers, ranchers, and other groundwater users have established a novel model for maintaining the aquifers upon which they depend for irrigation and other uses. As it would happen, this example also followed from the 2001-2004 drought. In this case, however, it came not as the result of an unprecedented shortfall of surface water, but instead from an extremely dry area suddenly realizing that an old strategy for dealing with precipitation shortfalls, namely, the unregulated pumping of groundwater by individual farmers and households, would no longer be able to be relied upon. The reason why was simple: from 1976 to 2002, this unregulated pumping - though described by many as a water source of last resort - had resulted in widespread declines in the water levels of the area's large underground aquifer. So much so, in fact, that many shallower wells were no longer able to function. Partly in response to the situation in the San Luis Valley, as well as groundwater supply overuse issues elsewhere in the state, the State of Colorado began to draw up additional regulations for groundwater found in non-tributary aquifers, with the intent of metering and potentially shutting down many wells like those found in the valley. In the face of the potential loss of this critical adaptation strategy - to say nothing of the tightly interconnected agricultural community that it supported - local community members set to work: Beginning with the formation of the Rio Grande Water Conservancy District, a wide array of concerned community members began a long and laborious process of developing a legally binding and financially self-sustaining mechanism for the self-governance of the San Luis Valley's groundwater resources. Ultimately, by leveraging

C___ Farms - Farming for Soil Health

A staunch advocate of what he calls "regenerative farming," Curtis S___ sees the landscape on which he produces dryland wheat, rye, and beef as more than just a parcel of land and natural resources. Rather, he sees a complex ecological system, in which wheat, cattle, and other directly beneficial organisms are but one part of the overall diversity of living and non-living components that make the system as a whole viable over the long-term. In addition to no-till practices and on-going efforts to eliminate fertilizer and other inputs, he also incorporates long-term grazing rotation plans in which cover crops on fallowed fields are used as forage for small, constantly moving cattle herds. Meant to mimic nutrient and carbon cycling seen under historic bison-dominated ecosystems, these practices are managed with the goal of restoring farmlands degraded by almost a century of traditional industrial agriculture by ensuring soil microbial health, soil structure, and biodiversity both below and above-ground. Working out of drought-prone Kit Carson County, he views these practices as also providing the additional benefit of reducing the risk of dust storms, minimizing erosion during the area's intense late summer rains, and helping soils to lock in as much moisture as possible due to improved soil structure.

As he notes, however, his efforts at C___ Farms do come with added costs. For example, while he has been experimenting to some success with companion cropping systems, in which nitrogen-fixing peas are combined with cereal crops, existing insurance programs do not cover such planting arrangements. Likewise, the task of understanding the complex - and often only slowly realized - effects of different soil-health focused practices requires both constant attention and tremendous patience. As a result, he sees a clear need for better support for this type of on-farm research and development, both in terms of federal and state programs, and more robust links between the scientific community and experimental farming operations.

assistance from the Federal Conservation Reserve Enhancement Program, the Colorado Water Conservation Board, the State of Colorado, and other regional sources, they arrived at a market based mechanism for groundwater control. In this new scheme, groundwater users would be charged a fee by the San Luis Valley Sub-District for each acre-foot of water pumped each year, which would be paid to the Sub-District itself. Likewise, should they choose to leave their fields fallow during drought periods to reduce their pumping needs, they would be compensated at a reasonable rate. In this manner, farmers would be able to weather drought periods while also maintaining the long-term sustainability of the aquifer: while they would pump less, they would not as easily face the risk of total shut-offs. Indeed, according to recent reports on their efforts, the combination of fees and fallow payments has resulted in over 30% reductions in groundwater pumping, and the widespread transition towards less water-intensive cropping systems.¹² These community level collaborations have also resulted in a number of “spin-off” innovations, as well, with projects underway to work with agriculturalists and ranchers to restore local river channels and riparian areas, protect local natural attractions, and improve the area’s access to real time meteorological and climate data.

This case, while unique in the sophistication and the legal scaffolding for community decision-making that it was able to build, is by no means alone. Statewide, farmers and agriculturalists of varied sorts have been increasingly involved in a variety of organizations meant to protect their livelihoods, ways of life, and to improve the sustainability of Colorado agriculture more generally. Perhaps the most visible example of this is the state’s “Colorado Proud” program, which allows Colorado agricultural producers to more effectively market within the state through the use of special signage and labeling in grocery stores and other outlets. Run by the Colorado Department of Agriculture, this program, in addition to providing labels and other marketing resources, also coordinates special events, educational opportunities for customers and farmers, and a variety of other support tools.¹³ Similarly, the Colorado Food Policy Network, a non-profit research and coordination coalition aimed at addressing issues of food insecurity, dietary quality, access to fresh, healthy food, and a variety of other initiatives aimed at improving the health of Coloradoans and the farms that feed them.¹⁴ At the same time as these “top-down” organizations are reaching out to communities, within communities themselves there are also hundreds of local, regional, statewide, and national agricultural sector or adjacent advocacy organizations currently active in the state, as well as a growing number of active year-round farmer’s markets.¹⁵ How much these potential sources of social, psychological, and financial support have directly impacted the lives of Colorado farmers has not been readily quantified. However, the significant and seemingly growing role of grassroots level organization around various industry interests suggests that there is demand within the system for solutions that go beyond existing institutional mechanisms. Through growing educational and other outreach programming, concerted lobbying, and significant inter-organizational cooperation, Colorado agricultural advocacy networks have demonstrated significant capacity to provide a platform for helping the state’s growing population learn about the realities and importance of farming, and for helping rural agricultural communities influence how policies are made around water use, water infrastructure planning, and various other statewide decision-making processes with implications for the ability to deal with weather-related downturns. Whether this will prove

sufficient to buffering the Colorado community against this year's and future shocks is unclear, of course, but it is likely that rapid developments in this area will continue apace.

In addition to building and utilizing social and cultural capital, a growing number of farmers across the state have also been long engaged an evolution of thinking with regards to how they manage and sustain the environments in which their farms are located. Much as is the case with ranching, this movement goes by a variety of names, ranging from simple "no till" farming to conservation, sustainable agriculture, restorative farming, soil farming, or eco-agriculture. Whatever the label, however, this movement generally tends to orbit around several key principles and practices developed in response to the vulnerability and excessive environmental impacts of traditional industrial agriculture. Perhaps most critical in this broader movement has been what agricultural researchers have called the "soil revolution," in which living, complex soil ecosystems are seen as the central component of a healthy agricultural landscape.¹⁶ Also common in this area is the use of planting and field preparation techniques that minimally disturb the soil structure, which in turn can allow for more effective soil water storage, more rapid absorption following storms, and better nutrient cycling for crops.¹⁷ Another common feature is the use of cover crops rather than bare fallowing, with species like clover and other nitrogen fixers serving to restore recently harvested soils while simultaneously protecting topsoil layers from erosion.¹⁸ These efforts are often also utilized alongside weed control techniques that utilize diverse, native plant communities to proactively exclude common agricultural weeds and pests, as well as to attract and sustain healthier populations of pollinator insects. As a result, advocates of this approach argue, farmers are able to simultaneously reduce negative environmental impacts from fertilizer runoff and other pollutants, increase the resilience of the ecosystems on which they depend to drought and flooding, and maintain livelihoods.¹⁹ Simultaneously, they improve and sustain local environmental values, in both cultural and financial terms. Sustainable farming and various derivations thereof have proven a powerful set of marketing tools, as well, as consumers in many markets become increasingly concerned about the impacts of their food consumption. By embracing sustainable agriculture approaches, then, farmers may be able to mount more effective defenses against the various hazards they face, be they weather- and pest-related or driven by the rapid social and economic change seen across the state.

These shifts in the practice of agriculture are also occurring alongside efforts by many farms to diversify their business models, either through on-farm sales, or by opening up their farms during certain parts of the year for various tourism-related activities. These range in character from classic corn mazes and pumpkin patches during the fall season to full-scale education and agricultural training facilities. Seen by many as a bridge between growing urban communities - who often know little to nothing at all about how food is grown - and the sprawling rural landscapes that farmers call home, these efforts allow farmers to supplement their incomes and generate community support, both of which are critical assets during times of weather-driven stress. Along these same lines, a number of farms, ranging in size from small 1-acre microfarms to larger, more conventional operations are also strengthening partnerships with local restaurants and other bulk food consumers as a means to leverage broader trends towards a preference for local food and "farm-to-table" dining options. These efforts are especially notable in the state's numerous mountain and resort towns, where

restaurants may face both elevated import costs and significant demand for ethically produced livestock, vegetables, and grains.

These are just a few of the technical, social, marketing, practice, and business planning innovations taking place within Colorado's 30,000+ farms. Though significant challenges remain - be they in the form of increasingly intense weather, increased pressure from urban growth, aging farm communities, or limited services in rural areas - these efforts represent a move toward resiliency in communities that might otherwise be facing down rapid livelihood and community decline. As policy makers consider how best to aid adaptation efforts in the agricultural sector, then, it is critical that they address not only the technical side of farming (i.e., crop varieties, watering technology, labor-saving tools, etc.) but the mechanisms that allow farming communities to organize, advocate, and pursue development in ways that mesh with their unique local values. For while weather and other risks will likely always be a part of farming life, it is the networks of supporters, customers, friends, and families that make up Colorado's farming communities that provide the most critical mechanism for pressing forward amid uncertainty. Likewise, while the importance of crop insurance programs and other federal subsidy programs is a necessary part of doing business in a changing world, so too must be programs that enable communities to innovate *as communities*, and develop the skills needed to work together to solve mounting problems of water scarcity, land use change, and the myriad of other challenges Colorado farmers face.

Outdoor Recreation and Tourism

Adaptation in the recreation and tourism sector in rural and mountain communities is extremely varied, both as a result of the many different business types captured therein, and because of the diversity of communities themselves. However, several themes have emerged over the last several years that bear recognizing here, as they too operate at the intersection of state and federal policy-making processes. Among the most important of these is that, given the overall dependency of the Colorado tourism economy on national and global economic processes and states of affairs, its ability to provide livelihoods can be seriously impacted by forces beyond local adaptations. Second, because of the way in which it is structured, with several extremely large and well-capitalized resort corporations operating alongside thousands of much smaller organizations ranging from local restaurant chains to part-time hunting guide operations, impacts from weather-related or external forces will almost always be borne unequally. From this, policy makers must also understand that strategies that prove viable for large, well-resourced operations may not be either feasible or functional in smaller businesses. Similarly, because of the diversity of economic structuring across the various tourism-dependent communities in the state, decision-makers must be able to tailor responses to specific community needs.

That said, several major adaptation strategies with implications across the sector are already underway. The most prominent and visible of these is snow-making, or the production of artificial snow. Used by all but a few ski resorts in the state, snow-making has allowed most operations to maintain full season operations despite extremely late starts to winter and dramatic shortfalls in total snow. By using water stored in reservoirs - usually gained via



Photo 14 - Ducks swim near river rafters in Browns Canyon National Monument. Credit: U.S. Department of the Interior (Wikimedia.org), 2015.

purchased senior water rights - in combination with electricity and specialized infrastructure, ski resorts have been able to buy back winter from the claws of drought for the time being. For those at lower elevations, such as Howelson Hill, future rises in temperature could mean a shortening of the period where snowmaking is effective. However, unlike other water uses across the state, controversy about the utilization of snow-making is generally minimal, as water lost to sublimation is relatively low, and all water used for snow eventually re-enters local watersheds at times when downstream communities need them most. As with other operations that rely upon stored water (and the rights needed to store it) however, even the most robust snow-making operation may struggle to be effective if several drought years occur in sequence.

What this has meant thus far for ski resorts and the towns that surround them is a need to figure out how to generate sufficient revenues from shorter, more unpredictable ski seasons. Thus far, they have been generally successful in this regard, with overall visitation and revenues at Colorado ski resorts continuing to climb despite slight dips in attendance in 2017.²⁰ This intensification of the ski season has not come without setbacks, however, as the unpredictability of ski resort opening times due to the variable beginning of snowmaking (and normal snowfall) and extraordinary pressure in most mountain communities in terms of developing and securing affordable housing for workers. Granted, this comes amid already serious pressure on the housing markets of Colorado and mountain communities in particular. In the narrow valleys and highland parks that characterize most mountain resort towns, real estate development, relatively small areas of easily developed land, and the rapid subdivision of large land holdings for luxury second homes all combine to drive prices out of the range of most service and tourism industry workers. Though many large ski resorts like Vail and Aspen are themselves working through a variety of programs to address this issue - including, in some cases, simply building or acquiring employee housing themselves - it remains unclear how these same pressures will be alleviated in towns where resorts lack the free capital to engage in this sort of civic engineering.²¹

Part of the reason housing costs - or rather, the ability to house a workforce - has become so critical for ski resorts is that, as another response to less predictable ski seasons and the variety of recreational opportunities Colorado provides, many resorts and mountain tourism communities are attempting to transform from simply “ski towns” and into year-long, all season tourism destinations. Indeed, many have already largely done so, with most large resort towns offering some form of year-round attraction or array of attractions, ranging from golf courses to more traditional activities like rafting, tubing, and fishing. As a result, however, this means that towns that normally dealt with a large seasonal worker pool must now also find ways to ensure that a growing number of year-round employees are able to afford local housing at a time when international investors, second homeowners, and real estate speculators of every stripe are driving prices upward.

Part of the transition to yearlong recreation and tourism plans for mountain communities, however, has meant that they are thereby exposed to all the varied stressors that Colorado’s increasingly hot and often dry summers can bring with them, particularly during years of drought and following widespread environmental damage from issues like wildfire or insect-induced tree death. In Salida, home to Monarch Ski Resort, partnerships between the resort, the local community, and the U.S. Forest Service have been undertaken to remove standing beetle-killed forest in the area for mulching and sale to local lumber yards.²² Similar efforts have occurred in the numerous recreational areas affected by beetle-kill in northwestern Colorado, where large concentrations of bark beetle mortality have long been an eye-sore and seeming

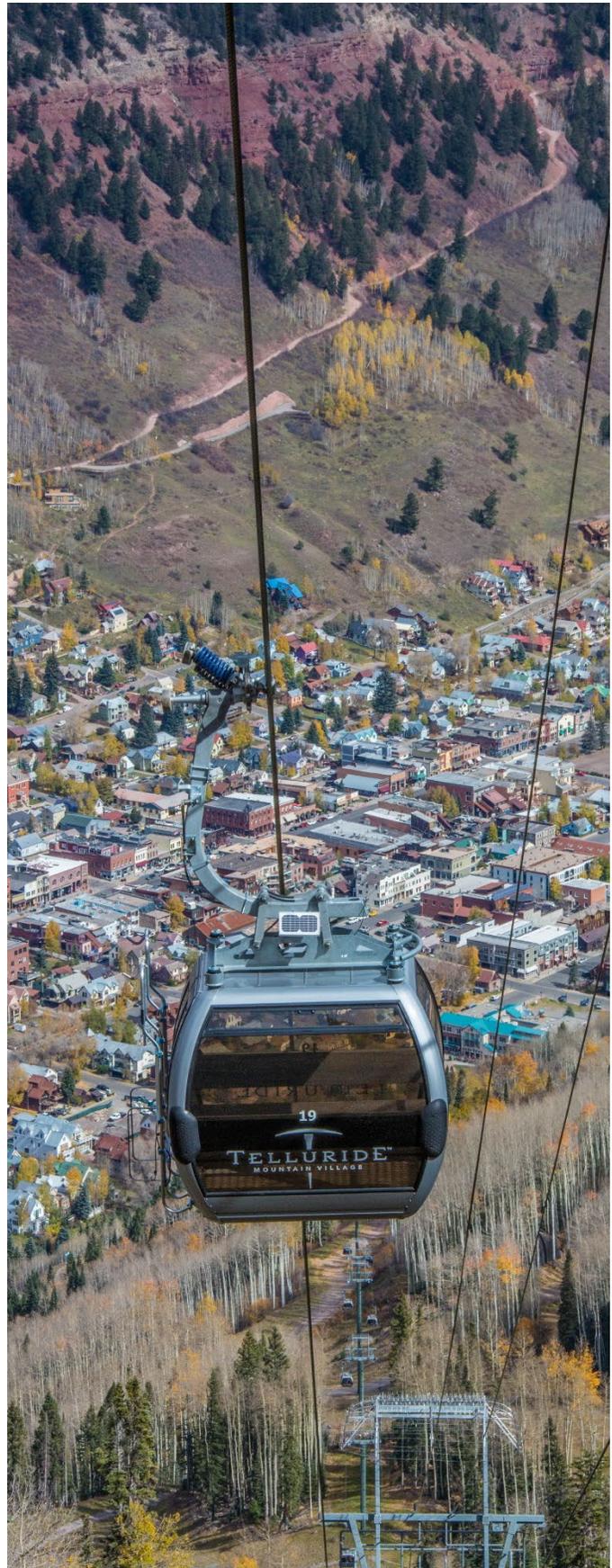


Photo 15 - Telluride Gondola, one of several "off-season" attractions in the area. Credit: Terry Foote (Wikimedia.org), 2009.

wildfire threat for local residents and visitors. There, funds from the American Recovery and Reinvestment Act and Colorado State Forest Service were utilized to establish beetle-killed lumber processing chains around 2010, albeit with only limited operations continuing today.²³ For although other numerous operations are on-going to find ways to capitalize on beetle-kill timber, the state's extremely small logging labor force (around 1,200 employees statewide) and lack of large, efficient lumber processing facilities make similar lumber from other states more cost effective for the large retail outlets on the Front Range.²⁴

Looking beyond the ski industry, adaptation in other types of recreational businesses is also taking place at a variety of scales. At the individual operation level, many recreational outfitters in hunting, rafting, fishing, nature tour, and other similar "guided recreation" businesses are undertaking a similar strategy of diversification seen in ski towns and agriculture. In this case, however, it comes in the form of both diversifying the type of services offered - many operations, for example, offer hunting and fishing tours; guided hikes and education; etc. - and in terms of the actual sites utilized. For example, several operators interviewed as part of research on the recreation sector in the Craig, Steamboat, and broader Gunnison basin found that many larger operations maintain a portfolio of destinations in the form of owned lands, leased private lands, and permitted public lands.²⁵ As a result, they are generally able to avoid areas undergoing localized shocks, thereby ensuring that their customers are satisfied under all but the worst weather conditions. River rafting outfitters are also looking at changing the way they schedule and organize their various types of runs, using periods of low flow for more family-oriented outings, and utilizing careful monitoring of river conditions to identify periods of the increasingly rapid spring runoff period are ideal for more intense rafting experiences.²⁶

Perhaps the most impactful efforts to adapt to changing resource variability in the broader recreation sector has come through cooperation with various state, county, and federal entities by different recreational industry advocacy groups. In the fishing, rafting, and general environmental recreation area, the State of Colorado's Instream Flow Program is one particularly notable example. Conceived as a means to work within the existing water rights adjudication system to maintain flows in Colorado's numerous rivers and streams, the In-Stream Flow program involves various state laws, statutes, and court rulings that allow the Colorado Water Conservation Board (CWCB) to develop and acquire water rights designed for the purposes of restoring and maintaining existing ecological process in stream channels. Among the first of its kind in the nation, this program allows the CWCB to place calls on junior water rights holders when stream levels fall below desired conditions at specific stream gauge or other monitoring sites. As a result, fish, wildlife, and plant communities - as well as the numerous businesses that rely upon them - are able to enjoy some degree of security, even drought conditions would otherwise cause rivers to run dry due to upstream diversions. Although a subject of significant controversy among those who feel such water is "wasted," and legal challenges from various different water user groups (e.g., agriculture, industry, municipalities) who feel that the Instream Flow Program represents a threat to historical use maximization orientations in the water sector, the program has demonstrated significant success in maintaining river levels in both upper watersheds and lower elevation areas. However, it is in play mostly in the western half of the state, and when enacted, can seriously hinder other types of water users (as they did this year in the Yampa basin).²⁷

Alongside efforts to maintain water levels in streams for wildlife and other environmental purposes, several examples of water providers, reservoir operators, and other authorities acting to maintain stream levels for recreational purposes have been noted over the last several years. This year saw particularly notable efforts in this vein on the Arkansas River, where extremely low snowpack levels threatened to shut down rafting, fishing, and other recreational activity earlier this year. Working within established agreements between users of Arkansas water in Colorado Springs, Pueblo, and at numerous downstream diversion points, the Arkansas Basin Roundtable implemented its Voluntary Flows Program to transfer water held in mountain reservoirs into the river itself. As a result, rafters, fishermen, and other river users were able to enjoy the Arkansas and its headwaters for much of the summer despite incessant drought conditions in the area as a whole. Bob Hamel, a representative from the Arkansas River Outfitter's Association - whose advocacy efforts have been a critical part of developing the Voluntary Flows Program - noted that such diversions relied heavily upon a common sense of fate among different Arkansas River users. Likewise, part of the program's continued success relies on consistent efforts to educate the public about how the program works, and the various ways that it might be utilized to protect recreational and wildlife resources. Further, while it has proven effective in maintaining river levels for rafting activity, continued research and monitoring will be required to ensure that the program is utilized effectively for the maintenance of fish and other wildlife populations.

Part of this type of effort's success might be explained by the overall character of the state itself: surveys by Colorado Parks and Wildlife conducted as part of the Statewide Comprehensive Outdoor Recreation Plan (SCORP) in 2013 found that 90% of Coloradoans participated in some form of outdoor recreation at least once per year, with roughly two-thirds of respondents (n=1,405) doing so more than once per week. In this same survey, 69.6% of respondents ranked "*Wilderness areas or open lands with little to no development and opportunity for solitude*" as very or extremely important.²⁸ Other work by the SCORP advisory group in 2014 also found that up just under 40% of all visits to tourism related businesses in the state are by Colorado residents themselves, some of whom regularly travel hundreds of miles to do so.²⁹

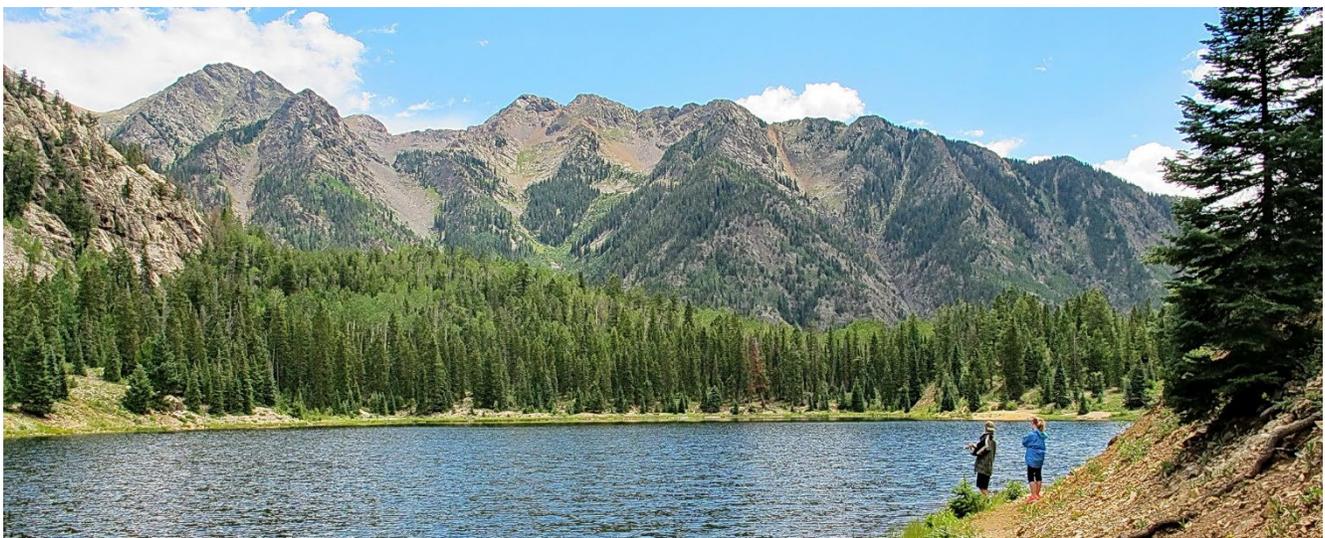


Photo 16 - Junior anglers fishing outside of Durango, CO. Credit: AI_HikesAZ (Flickr.com), 2013.

Equally important, no doubt, has been the work of the state's numerous outdoor industry advocacy organizations, and the variety of different community, non-profit, government, and environmental advocacy group connections that they have been able to establish over the last century. For example, the Pikes Peak Outdoor Recreation Alliance - focused solely on the region centered just to west of Colorado Springs - includes over 40 such organizations, including numerous cities, government agencies, resorts, and outdoor gear manufacturers. The Colorado Association of Ski Towns, a similar organization, brings together the municipal governments of most of the state's ski resort locations to share information on problem solving in a variety of areas, from developing effective urban infrastructure in mountainous areas to how to more effectively minimize impacts to surrounding wildlife as a result of population growth. Colorado Ski Country USA, as the name suggests, represents a coalition of 24 of the state's ski resort areas that works actively to influence public perception, media discourse, and legislation on behalf of Colorado resorts.³⁰ The Colorado Wildlife Federation, in operation for 65 years, represents "*anglers, hunters, wildlife viewers, wildlife photographers and other who believe in the stewardship of a wildlife population that defines our state heritage and traditions*", and does significant state and federal level lobbying work around issues of concern regarding species habitat protection, funding for public lands, and protections for endangered species.³¹ Colorado Trout Unlimited, a cold-water fisheries, river restoration, and conservation advocacy group is highly active in the state on a variety of fronts, and has played a major role in multiple important court cases surrounding water use, environmental management, and specific programs like the Instream Flow Program.³² The Rocky Mountain Climate Organization, a newly formed research and advocacy group in state, has recently put out a comprehensive report on climate-driven risks to the headwaters basins of the state for the Northwest Colorado Council of Governments, a regional coalition representing 6 of the state's most heavily trafficked recreational tourism counties.³³

The list goes on: these are just a few of the numerous activity- or regionally-driven advocacy groups that interface with - and often act to directly benefit - the outdoor recreation industry. Given the broad scope of this project, it remains unclear just how well these various groups are enabling adaptation on the ground, particularly in the case of the thousands of small businesses and part-time recreational outfitting operations that make up the majority of the state's recreational workforce. However, what it does demonstrate is that the industry as whole has shown a proven capacity to influence political and natural systems at impressive scales, and will likely continue to do so until drastic changes occur. While deepening drought, particularly spectacular wildfire seasons, or catastrophic mountain flooding might cause serious impacts over the short term, and in specific places, it would seem that the recreational sector as a whole possesses a variety of mechanisms for reconfiguring itself in the face of the variety of shocks it has seen thus far. Whether or not this will be sufficient over the long-term remains to be questioned. However, it seems likely that, whatever transpires, the natural and recreational resources the industry relies upon will continue to be defended by a wide array of advocates at a variety of levels.

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Conclusion: Empowering Innovation and Adaptation

Given both the broad scope of risks faced by rural communities and the range of strident adaptation efforts already underway, the task of empowering those hoping to innovate and adapt in rural areas is far from simple or clear. At the same time, the degree to which truly adaptive efforts are taking place in all rural areas should not be overstated. Though many communities and individuals are taking action to better cope with and respond to the increasing challenges brought by 21st century weather - and may, indeed, provide valuable lessons for those seeking to do the same - many rural communities, small agricultural operations, and low population mountain towns in Colorado may lack the basic financial, infrastructural, technical, and scientific capacities needed to enact even the most straightforward adaptation strategies. Moreover, strategies that may be applicable in the eastern plains may not apply to the mountainous western portions of the state; likewise, rural areas within the reach of future urban growth and demands for water may face challenges that go beyond local level adaptations to change. If it is the goal of decision-makers - be they policy makers, land managers, or government employees - to support the vitality and resilience of all Coloradoans, significant efforts at a variety of scales and using a variety of methods will need to be undertaken. Generally speaking, those interested in assisting and empowering adaptation processes will have to tailor their efforts to the needs and views of the diverse rural communities they hope to support, and in doing so find new ways to work alongside at times fiercely independent, deeply rooted communities. Here, we present some of the directions that such efforts might turn to, based both on the recommendations of on-the-ground actors in rural communities with which we spoke as well as the broader findings of this report.

- **Improve the capacity of leaders and decision-makers to identify areas of high vulnerability and low indicators of adaptive capacity as a means to strategically support the highest vulnerability areas.**

Not all rural communities face the same risks, nor are they all equally capable of responding to the risks they face. Given limited resources, the ability to target program funds, technical expertise, and other efforts in places where the greatest impact can be achieved is essential to maximizing overall adaptive success. In many cases, however, it is the areas with the greatest financial, social, and political resources that are best able to take advantage of state and national programs. As efforts to plan for Colorado and the nation's future continue, finding ways to engage these least-resourced communities in the conversation will be critical to ensuring that those who need the most help are not left behind.

- **Support existing collaborative networks and advocacy efforts focused on rural and mountain communities well-being, and encourage the development of such networks where they are absent. At the same time, develop ways to connect with existing local leaders and other community gatekeepers.**

Rural communities may be rightfully resistant to efforts by outsiders to transform their communities and ways of life. As a result, working within existing organizations - ranging from sector advocacy organizations to local community groups - can help to bridge cultural and conceptual gaps, build trust within communities, and provide

accurate information on the specific problems at play in a given area. These networks, in addition to assisting in the process of adaptation, itself, can also provide a critical resource during periods of disaster or other weather-related hardship in both tangible and intangible ways.

- **Maintain and/or expand funding and capacity within existing knowledge sharing mechanisms, such as the Colorado State University Extension Service, and improve their ability to engage communities on issues of weather and climate risks.**
The CSU Extension, USDA field offices, and other existing conduits for transmitting scientific and technical innovations to rural areas have long been a critical asset to farmers, ranchers, and others working with Colorado lands. In addition to having the trust of the communities in which they work, extension agents and their counterparts also often have a highly developed understanding of local-scale issues in need of addressing. However, the ability of these organizations to educate and inform communities on issues related to weather and climate risks is limited. New funding streams and programs may need to be developed within these organizations to address these issues to ensure that existing responsibilities can still be met.
- **Support and encourage innovative approaches to locally-driven sustainable resource management and governance, especially in terms of water and public land resources.**
Efforts such as the San Luis Valley’s novel approach to self-governance around groundwater and the collaborative work happening between local governments often require careful navigation of existing legal and policy frameworks at the state and national level. In addition to capturing the lessons learned in these types of efforts, programs to disseminate these lessons and improve overall community understanding of complex topics (such as Colorado water law and basin-scale hydrology) have the potential to ensure that community level efforts are not stymied by factors at play at scales beyond their normal range of concern.
- **Improve the capacity of existing insurance and disaster relief programs to address the real needs of Colorado agricultural and recreational operations**
As noted by several participants in this project, Colorado’s farming and ranching landscape is already transforming in ways with serious implications for its ability to face down future weather-related risks. However, existing programs for crop insurance and disaster relief in agriculture focus largely on large-scale commodity crops, leaving diversified, specialty crop, microfarming, and other sorts of innovative agricultural businesses with limited options following extreme weather impacts. Although national policy hurdles may be insurmountable at this time, future efforts to protect agricultural operations may benefit from taking a more sophisticated view of the types of agriculture that is supported by government subsidies and other programs, and find ways of encouraging adaptive, sustainable practices through these mechanisms. In addition to finding ways to insure these “non-traditional” types of agricultural operations, programs might also be developed to further incentivize Colorado consumers to support local agricultural activity.
- **Encourage participation of farms, ranches, and recreational operations in scientific research and development**
As discussed in previous sections, many farms, ranches, and other land-based livelihood practitioners are constantly engaging in different types of experimentation as a means to improve the viability of their operations and ensure their capacity to pass

on healthy landscapes to those who come after them. However, at this time much of this type of activity occurs in isolation, with valuable lessons and insights often being left to the individuals themselves to record and share with others. Through improved engagement by the scientific community with local level operators, it is possible that the overall ability of the agricultural and recreation industries to learn about and appropriately respond to weather-related risks will be improved. That said, such a strategy would require both financial resources and the improvement of the ability to the scientific community to collaborate with those who make their living off of the land. Improving efforts within the state's universities to train researchers and scientists in applied, collaborative research may therefore be required.

- **Continue to develop and improve programs that reward long-term perspectives and approaches to ensuring both business and ecological sustainability**

As noted above, one of the most important strategies being utilized by farmers and ranchers to cope with issues like drought and flooding are those that involve a shift away from the pursuit of short term commodity gains and toward a more holistic, long-term view of the well-being of the landscape that their livelihoods rely upon. However, the benefits of these types of approaches may take significant time to be realized, and costs associated with adopting such approaches may be prohibitive to farmers, ranchers, and others who are already suffering under the burden of weather and economic stress. Grants, loans, and subsidies - as well as mechanisms for informational and social support - should be developed that help to encourage approaches to land and natural resource use that improve community resilience and promote the long-term sustainability of the state's ecosystems and agricultural productivity.

Granted, these are only some of the many, more detailed, more place-specific approaches that will likely be required should communities hope to truly adapt to current and future weather-related risks. Nevertheless, we present these suggestions here in the hopes that they will encourage the imagination and creativity of decision-makers at various levels as they work to address the needs of both rural and urban Coloradoans. In terms of research, future efforts should continue to explore and widen awareness of the local level dynamics at play in rural communities, as it is only through understanding how these communities view, value, and move through the world that we can develop ways to support their well-being. Similarly, given the significant risk of conflict that exists between growing urban populations and the rural areas surrounding them, these efforts should also look to new ways of bridging the urban-rural divide, and to make sure that the rapid innovation and adaptation efforts happening within large cities can translate effectively to the small towns and isolated communities where weather-related risks may be more acute.