



Cultivating Equitable Responses to Increased Aridity in the US Southwest: The Climate Assessment for the Southwest Progress Report: June 1, 2022–May 31, 2023

Contact

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Photo by Gigi Owen

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WHAT IS CLIMAS?

The Climate Assessment for the Southwest (CLIMAS) is a NOAA-funded program that connects researchers and professionals at the University of Arizona, New Mexico State University, and the Inter Tribal Council of Arizona to partners from the private sector, academia, and local, state, federal, and tribal governments. Since 1998, CLIMAS has brought the best available scientific knowledge to weather and climate-related challenges in the Southwest. CLIMAS is funded by the NOAA Climate Adaptation Partnerships (CAP) Program (formerly known as Regional Integrated Sciences and Assessments, or RISA), which is designed to improve the use of climate information in decision making.

2022–2023 CLIMAS RESEARCH TEAM

Principal Investigators

Daniel Ferguson – CLIMAS Lead Investigator and Director; Assistant Professor, Environmental Science, University of Arizona

Heidi Brown – Associate Professor, Public Health, University of Arizona

Michael Crimmins – Professor & Extension Specialist - Climate Science; Environmental Science, University of Arizona

David DuBois – New Mexico State Climatologist; Assistant Professor, New Mexico State University

Ben McMahan – Assistant Research Professor, Arizona Institute for Resilience, University of Arizona (through October 2022)

Alison Meadow – Associate Research Professor, Office of Societal Impact, University of Arizona

Gigi Owen – Assistant Research Scientist, CLIMAS, Arizona Institute for Resilience, University of Arizona

Connie Woodhouse – Professor, Geography, Development, & Environment, University of Arizona

Co-Principal Investigators

Erika Austhof – Research Specialist, Public Health, University of Arizona

Stephanie Carroll – Assistant Professor, Public Health Policy and Management; Associate Director, Native Nations Institute, University of Arizona

Bonnie Colby – Professor, Agricultural and Resource Economics, University of Arizona

George Frisvold – Professor, Agricultural and Resource Economics, University of Arizona

Hatim Geli* – Assistant Professor, Agricultural, Consumer and Environmental Sciences, New Mexico State University

Christina Greene – Assistant Research Scientist, CLIMAS, University of Arizona

Kelly Jendrisak* – Air Quality Coordinator, Inter Tribal Council of Arizona (ITCA)

Ladd Keith – Assistant Professor, Landscape Architecture & Planning, University of Arizona

Lara Prihodko* – Associate Professor, Animal and Range Sciences Department, New Mexico State University

CLIMAS Staff & Postdoctoral Researchers

Trevor McKellar – Postdoctoral Researcher, CLIMAS, University of Arizona

Matthew Meko* – Applied Climatologist, CLIMAS, University of Arizona

Stacie Reece* – Program Manager, CLIMAS, University of Arizona

Research Affiliates

Laurel Bellante – Assistant Director, Center for Regional Food Studies, University of Arizona

Ashley Bickel – Economic Impact Analyst, Agricultural and Resource Economics, University of Arizona

Michael DeAntonio – Research Scientist, New Mexico State University

Madeleine deBlois – Research Scientist, Community Research, Evaluation & Development, University of Arizona

Dari Duval – Economic Impact Analyst, Agricultural and Resource Economics, University of Arizona

Stan Engle – Research Staff, New Mexico State University

Andrea Gerlak – Director, Udall Center - Studies in Public Policy, University of Arizona

Rachel Gildersleeve* – Research Professional, Community Research, Evaluation, & Development, University of Arizona

Rey Granillo – Development and Information Technology, Arizona Institute for Resilience, University of Arizona

Zack Guido – Assistant Research Professor, Arizona Institute for Resilience, University of Arizona

Amanda Hilton* – Assistant Research Scientist, Bureau of Applied Research in Anthropology, University of Arizona

Ashley Hullinger* – Program Director, Water RAPIDS, Water Resources Research Center, University of Arizona

Sarah LeRoy – Science Applications & Communications Coordinator, Southwest Climate Adaptation Center, University of Arizona

Rachel Leih* – Research Professional, Community Research, Evaluation, & Development, University of Arizona

Aaron Lien – Assistant Professor, Natural Resources and the Environment, University of Arizona

Mitch McClaran – Professor, Natural Resources and the Environment, University of Arizona

Craig Rasmussen – Professor, Soil Water & Environmental Science, University of Arizona

Marcel Schaap – Professor, Soil, Water and Environmental Science, University of Arizona

Graduate and Undergraduate Student Researchers

Kacy Bartels*

Anvi Bhakta*

Karrington Hamilton*

Hannah Hansen

Dharma Hoy

Stephanie Smith*

Ning Zang*

Environment & Society Fellows

2022

Julia Davies

Jake Dean

Rachel Zollinger

2023

Talia Anderson*

Lucas Belury*

Hannah Friedrich*

Majerle Lister*

** denotes new additions to the CLIMAS team during the reporting period*

CLIMAS BY THE NUMBERS 2022–2023

Presentations Given to Stakeholder & Academic Audiences: 80
Advisory Roles Served: 26
Academic Articles Published: 23
Research Reports and Briefs: 11
CLIMAS-related Master's Theses: 3
CLIMAS-related PhD Dissertations: 1
Climate Briefs Disseminated: 36
CLIMAS-related Twitter Followers: 6951
Podcasts Recorded: 7
Workshops, Seminars, & Trainings Facilitated: 29
Appearances in the Media: 38
Related New Proposals Funded: 22



Photo by Christina Greene

NEW AREAS OF FOCUS OR PARTNERSHIP

In fall 2022, CLIMAS began a new grant cycle focused on creating equitable climate responses in four main topical areas: increasing aridity, issues with water availability, heat, and public health. While building on our regional expertise and established community, governmental, and institutional connections, we aim to develop new partnerships with people and communities on the frontlines of climate change in Arizona and New Mexico.

Aridity: Increasing aridity is contributing to substantial increases in wildfires in the region. This year, the project team connected with multiple researchers to understand wildfire science and planning needs and build support for engaged research with rural communities facing wildfire risk.

Health: Stakeholders from previous CLIMAS work indicated specific interest in issues around health and prescribed wildfire and health and green infrastructure. The project team is diving further into these topics.

Heat: Building on their expertise in urban heat, this research team is expanding their scope to help support rural, tribal, and U.S.-Mexico border communities to address increasing

heat hazards. A survey about rural, tribal, and border heat resilience will be distributed in summer 2023 to understand the unique challenges they face.

Water Availability: The project aims to investigate relationships between climate and streamflow in northern New Mexico. This year, the team researched the cultural, political, economic, and legal contexts around water availability in the Rio Grande basin and connected with several researchers and stakeholders in that region to learn how this project could best support community-level needs.

To help support these project efforts, CLIMAS is also building **Collaborative Climate Services** that provide climate information tailored to specific stakeholder and project partner needs; providing **Education and Training** to build the adaptation workforce and increase the capacity of researchers, graduate students, community partners to engage in collaborative climate research; and creating an iterative and interactive **Evaluation and Learning Agenda** to document and enhance the process of generating useful climate information, effective community engagement, and tangible evidence of societal impacts of CLIMAS work.

FEATURED ACCOMPLISHMENT

With the start of this new funding cycle, the CLIMAS program has undergone a shift in approach to better conduct inter- and transdisciplinary research. Our integrated project teams are interdisciplinary in terms of researcher background and we aim to make project teams transdisciplinary by involving multiple types of knowledge and experience into the research design and process. This shift has involved several personnel and operational changes, which began over the last year. These changes include: hiring a new program manager and applied climatologist; welcoming new CLIMAS investigators at New Mexico State University; building

CLIMAS's relationship with the Inter Tribal Council of Arizona; establishing connections with researchers and partners in New Mexico; developing a community engagement database and ethical standards for engaging with frontline communities; increasing our collective understanding of Indigenous research governance and data sovereignty through training; and creating an iterative program evaluation and learning agenda that evolves over the course of the funding cycle. We believe that these incremental changes will add up to a larger scale shift toward building equitable responses to climate challenges in the Southwest.



Photo by Gigi Owen

OUTREACH AND ENGAGEMENT

CLIMAS researchers gave presentations, hosted workshops, and used several online communication tools such as newsletters, data hubs, and interactive websites.

CLIMATE INFORMATION TOOLS

The Southwest Climate Outlook (SWCO)

SWCO summarizes climate and weather information from disparate sources in nonscientific language, providing more than 1,600 people with monthly climate-related information. Since SWCO's inception in 2002, stemming from the END InSight project, the publication has evolved into a tool for two-way communication with stakeholders and a platform for responding to needs throughout the region. Eight issues were distributed between June 2022 through May 2023. There was a pause between the October 2022 issue and the March 2023 issue due to staffing changes. The March 2023 issue showcases the newer format of ArcGIS StoryMap. climas.arizona.edu/swco

Rainlog.org Monthly Climate Summary Email Newsletter

M. Crimmins authored and sent twelve newsletter issues between June 2022–May 2023 to subscribers and those who log rain event totals.

Arizona Seasonal Climate Summary. Arizona Range and Livestock Newsletter

M. Crimmins authored quarterly climate summaries for this newsletter produced by University of Arizona Cooperative Extension.

The Southwest Climate Podcast

CLIMAS scientists discuss climate-related issues in monthly climate podcasts. The podcasts synthesize information from disparate sources that often do not have a Southwest bent, translating the national and global discussions into what it means for the Southwest. Seven episodes aired between June 2022 through May 2023. There was a pause between the November 2022 episode and the February 2023 episode due to staffing changes. climas.arizona.edu/media/podcasts

University of Arizona Extreme Heat Network

L. Keith distributes a monthly newsletter to 200+ subscribers from across the U.S. Other members of the network send requests to help promote their opportunities, such as grants or partnerships, related to heat. heat.arizona.edu

SOCIAL MEDIA

New Mexico Climate

David DuBois continued his use of Twitter via the NM Climate Center account (@nmclimate). This account had 3,262 followers as of June 2023. Activity on this Twitter account generates off-line conversations with local and national media. DuBois posts information, graphs, statistics, and photos of dust storms that impact southern New Mexico. NM Climate is also on Instagram (<https://www.instagram.com/nmclimate/>) with 1,373 followers.

CLIMAS Twitter

The CLIMAS program's Twitter account (@CLIMAS_UA) has 1,039 followers as of June 2023. Posts that generated the highest amount of interest were related to job announcements, guest speaking events, summer monsoon, the Southwest Climate Podcast, and the Southwest Climate Outlook.

CLIMAS LinkedIn

(<https://www.linkedin.com/in/climas-ua-5094a6269/>) In 2023 the CLIMAS program created a LinkedIn profile. As of June 2023, there were 74 connections in the CLIMAS network and 23 views of the profile.

CLIMAS PI M. Crimmins (Twitter @mike_crimmins) posts on climate conditions, drought impacts, tools/information and retweeting CLIMAS products like SWCO and podcast. He has 983 followers and posted about 100 tweets over past year.

CLIMAS PI L. Keith (Twitter @laddkeith) posts about extreme heat conditions, urban planning, and climate change in the southwest. He has 1,667 followers and posts regularly. His LinkedIn (<https://www.linkedin.com/in/laddkeith/>) has 2,900 followers with a strong presence from planning and climate adaptation practitioners.

DATA HUBS AND ONLINE TOOLS

Southwest U.S. Summer Monsoon Season Precipitation Mapping: A near real-time monsoon season precipitation mapping system was developed in May 2019. Several updates were added to maps and charts in 2020 and 2021. This mapping product is often used for the SWCO and podcasts. In 2022, the product was integrated into a revised National Weather Service monsoon tracker: [Tracking the Monsoon](#). New state-level map pages for [Arizona](#) and [New Mexico](#) were added in 2022.

Southwest Monsoon Fantasy Forecasts: Players estimate the total monthly precipitation at each of the five major cities in the U.S. Southwest Monsoon region: Tucson, Phoenix, Flagstaff, Albuquerque, and El Paso. Points are awarded each month depending on the accuracy of the estimate compared to the actual observed rainfall. The goal is to accumulate the most points over the July, August, September period. The game was piloted in 2020 via the [Southwest Climate Podcast](#), hosted by CLIMAS researchers M. Crimmins, Z. Guido, and B. McMahan.

Southwest U.S. Station Climate Summaries: This hub houses station-based climate monitoring plots for 118 stations across Arizona and New Mexico. Interactive historical plots of temperature and precipitation were added this year for each station with updated website and near-real time updates to plots each morning.

Standardized Drought Index Visualization Tool: This interactive R-based Shiny app can be used to plot and explore drought indices calculated using NOAA NCEI climate division data. Plots are used in state level drought monitoring, by other climate monitoring efforts, and for general CLIMAS related outreach effort. Several updates were added in 2021.

myRAINgeLog: This online data management and visualization tool is designed for ranchers and land managers who collect and interpret cumulative precipitation observations at remote sites. The account-based tool allows users to collect, manage and analyze multiple gauges and share observations through a public mapping feature. Custom reports can be generated for each gauge with accompanying charts of observations against historical climate conditions and summaries of field notes and photos entered by the user. The site is updated daily. The tool has continued in development as part of a broader rangeland precipitation monitoring program that started in 2017. New features were added in 2022, with additional training workshops conducted online in 2021. A new [YouTube channel](#) with how to videos was also added in 2021.



Photo by Zack Guido



Photo Courtesy of Pima County Food Alliance

Arizona Station-based Drought Tracker: A new, real-time station-based drought tracking page was posted in spring of 2021 to assist with short-term drought monitoring in Arizona. This tool accesses precipitation data from over 1300 rain gauges from different networks including volunteer observers (e.g., Rainlog.org, CoCoRAHS, and home weather stations) to develop drought index values at time periods from the most recent 30 days to the past 365 days. The intention of this tool is to support fine scale adjustments of the U.S. Drought Monitor map across Arizona using as much observation data as possible.

Burn Period Tracker: A new monitoring tool developed in collaboration with the Southwest Coordination Center that provides access to an experimental fire weather monitoring product called the Burn Period Tracker. Burn period is defined as the number of hours per day where the hourly average relative humidity is less than or equal to 20% and is calculated at Remote Automated Weather Stations with real-time data and several years of historical data. Values range from 0 to 24 hours per day with higher values associated with increased fire danger. This tool is being used by fire managers working across the Southwest.

Southwest U.S. NFDRS Charts: A new monitoring tool developed in collaboration with the Southwest Coordination Center depict real time and forecasted values of two standard fire danger indices part of the National Fire Danger Rating System: Energy Release Component and Burning Index. Charts are updated each evening using NFDRS data from the Weather Information Management System and plotted against climatological information generated for each Southwest Predictive Service Area by FireFamily+. This tool is being used by fire managers working across the Southwest.

Cooling Center Maps for Tucson, AZ: Maps of cooling center locations were developed and maintained for the City of Tucson and Pima County in AZ. H. Brown and L. Keith worked with Arizona Department of Health Services and the Pima Association of Governments to distribute the information more widely.

Plan Integration for Resilience Scorecard™ (PIRSTM) for Heat StoryMap: Visual storytelling for spatially evaluating networks of plans to mitigate heat. Project led by L. Keith (University of Arizona) and S. Meerow (Arizona State University).

Community Drought Data Hub on ArcGIS Online: A. Hullinger. From this platform, online visitors can link to three different Hub portals to access local and regional climate and water data for their community, as well as mapping and visualization tools to explore these resources.

SELECTED WORKSHOPS AND SEMINARS

American Meteorological Society’s 14th Conference on Environment and Health at the AMS 103rd Annual Meeting: E. Austhof, Co-chair for the Environmental Links to Infection, Pain, and Disease Session. This session brought together researchers from both climate science and environmental health. January 9, 2023. Attended by approximately 50 people.

AIR Societal Impacts Framework Development Workshops: G. Owen and A. Meadow. Monthly, January–May 2023. AIR programs are designed to have tangible impact in society, both within and beyond the realm of academia. However, we currently don’t have an institutional framework or reporting mechanism to help us identify and document the impacts we have in the world. This workshop series convened AIR program leads and coordinators to a) strengthen their background in societal impact evaluation and documentation and b) co-develop a reporting mechanism to capture the breadth of impacts across AIR programs. This process will also serve as a pilot for other departments around the University of Arizona campus. This work stemmed from the CLIMAS program evaluation. Feedback to the workshop series was enthusiastic.

Introduction of the HHS Environmental Justice Index (EJI): L. Keith hosted U.S. Assistant Secretary for Health, Admiral Rachel Levine, at the University of Arizona on December 13, 2022. This was organized in collaboration and support with the Udall Center with additional support from the UA RII.

Global Heat Health Information Network’s Management Committee Meeting and Inaugural Open Forum: L. Keith hosted the GHHIN at the University of Arizona DC Center from February 27 to March 3, 2023. This was organized in collaboration and with support from the UA RII.

City of Tucson Urban Heat Island Workshop: A. Meadow co-hosted the workshop with Irene Ogata from Tucson Water. Ms. Ogata convenes an Urban Heat Island (UHI) workshop every year to provide professional development to City and County staff about heat issues in the region, with a particular focus on how landscape can help to reduce UHI. There were 15 people in attendance held in November 2022.

Drought Response Planning Workshops: A. Hullinger held three workshops, one for small towns, one for the Town of Patagonia, and one for the Town of Superior. Attendees ranged between 16–24 and included local leaders, community members and natural resource managers. Goals of the workshops were to evaluate drought vulnerability for their community and assess policies or plans in response to climate threats.

Footprints Running Camp: Mentor. G. Owen. July 2022, San Juan Mountains, Colorado. Helped develop climate action projects with 10 campers (ages 21–43) from across the country.

SELECTED ONLINE CONTENT – PODCASTS, OPINION PIECES, BLOG POSTS

The Public Health Epidemiology Conversations (PHEC) Podcast: Episode #265 Climate Change in Public Health with Erika Austhof, MPH, 2022.

Come Rain or Shine Podcast: Crimmins, M. and C. Woodhouse. Megadrought and Aridity, USDA Southwest Climate Hub and DOI Southwest Climate Adaptation Center, Season 3, episode 9, Sept 2022.

WRRC Getting Out in Arizona – Drought Planning in Patagonia. A. Hullinger. WRRC Newsletter, March 31, 2023.

Extreme heat is here. Here’s how we create a heat-resilient nation. L. Keith. Smart Cities Dive. July 13, 2022.

Heat Risks are Rising in Cities Worldwide — Here Is How to Plan for Urban Heat Resilience. S. Meerow, Sara and L. Keith. (2022) The Nature of Cities. June 13, 2022.

What does resilience mean to ranchers. Walsh, K., C. Greene, H. Wilmer, D. Ferguson, M. Crimmins, and M. McClaran. 2022. ArcGIS Storymap.

HIGHLIGHTED PRESENTATIONS

AAG Annual Meeting: C. Greene was a panel member of the Bringing Equity into Climate Adaptation Partnerships: Challenges and Opportunities. Panel was organized by several CAP/RISA researchers. Approximately 40 in person attendees. The panel served to build relationships across CAP/RISA and is hoping to formalize these relationships and knowledge exchange through a formal CAP/RISA Community of Practice.

Southwest Water Resilience Conference (Salt River Project): C. Woodhouse. The Influence of Climate on Salt and Verde River Streamflow, Phoenix, AZ. October 27, 2022. There were approximately 100–200 attendees made up of Salt River Project’s stakeholders. Woodhouse provided some baseline information about surface water supply (Salt and Verde streamflow) and climate, and how those relationships have been changing. Related to CLIMAS Project: The Influence of Climate on Lower Colorado Streamflow Variability: Present, Past, and Future.

Arizona Hydrological Society Annual Meeting: C. Woodhouse. The influence of climate on Gila River basin streamflow. Tucson AZ, September 15, 2022. Woodhouse

presented on a session on hydroclimate. Related to CLIMAS Project: The Influence of Climate on Lower Colorado Streamflow Variability: Present, Past, and Future.

NSF Project in the Upper Rio Grande/San Luis Valley of Colorado. C. Woodhouse. Interactions with Craig Cotton, District 3 (Rio Grande) Engineer for the State of Colorado and Wylie Keller, a water resource specialist at the Rio Grande Water Conservation District. Woodhouse gave a presentation in November on upper Rio Grande streamflow/ climate relationships.

EPA Creating Resilient Water Utilities – Train the Trainer: D. Ferguson. May 2023. Through the CLIMAS partnership with ITCA, D. Ferguson was invited to present climate resilience to trainers for the U.S. EPA’s Creating Resilient Water Utilities (CRWU) program. There were approximately 20 people in attendance. Training focused on water utilities for all of Indian Country in EPA Regions 5 through 10. The presentation provided an overview of each of those 6 EPA regions in terms of climate impacts and how they differ across those regions.

NEW MEXICO OUTREACH HIGHLIGHTS

Drought Learning Network: D. DuBois. USDA Southwest Climate Hub, online, “Expansion of our state-wide weather network, the ZiaMet mesonet”, (November 9, 2022). Approximately 10 attendees who were mostly tribal natural resource staff and land owners on tribal land. This was part of the effort to find ZiaMet site hosts on tribal land in New Mexico.

National Speakers Conference: D. DuBois. The State Legislative Leaders Foundation, Santa Fe, NM, “Battling Wildfires: Is Your State Ready?”, (August 25, 2022). There were 50 attendees. DuBois was invited by Representative Nathan Small of the State Legislature. Discussion was about the role of climate and weather patterns that impact wildfires.

NMSUCCESS NMSU Climate Change Education Seminar Series: D. DuBois convened a series of 6 seminars with guest speakers at New Mexico State University in Las Cruces, NM. They have continued these workshops due to the success

from the past couple of years and the desire from the community to know more about climate change and to influence others. The series was to provide some advances in climate literacy to the general public. The speakers invited to speak this year addressed mitigation, community response, and impacts of climate change to our water resources. Attendance varied from 25–50 people at each event.

FEMA Region 6 Climate Mitigation Workshop: D. DuBois, FEMA, online, “Climate change impacts and outlook for NM”, (July 12, 2022). This was a virtual panel with three other State Climatologists from Region 6 to discuss high priority climate topics with approximately 60 in attendance. Presentation addressed high priority extreme weather phenomena affecting Region 6 states with some emphasis on New Mexico.



Photo by Dan Ferguson

SELECTED RESEARCH FINDINGS AND HIGHLIGHTS

EVALUATING EXISTING AND DEVELOPING NEW DROUGHT INDICES USING MODELED SOIL MOISTURE TIME SERIES

This project developed a novel modeled soil moisture dataset for the Southwest and evaluated two commonly used drought indices. This work highlights how drought events at different soil depths are strongly related to seasonal patterns in precipitation and that drought index timescales should be optimized to follow these patterns. Results suggest how to best use drought indices for soil moisture monitoring across the Southwest. Other key results include:

- The Standardized Precipitation Index was found to better represent soil water availability in soils of the semi-arid Southwestern United States.
- The relationship between meteorological index timescale and soil water depth operates roughly on a 1-month to 5cm step progression at shallow depths (<80cm).
- Analysis by soil type shows that clay loam soils produce shallower sloped timescale- depth relationships and higher correlations compared to sandy soils.

IDENTIFYING GAPS IN STAKEHOLDER NEEDS REGARDING THE CLIMATE-HEALTH CONNECTION

A national survey was distributed from June 14 to July 15, 2020 (n=200) and from July 15 to August 14, 2020 (n=300). Survey results suggest that when it comes to climate change and health information, respondents trust their primary care doctor or a climate scientist more than the

Center for Disease Control, the Environmental Protection Agency, the World Health Organization, or even local health departments—all of which are agencies that develop and distribute climate change and health information (see Figure 1).

How much do you trust or distrust each of the following as a source of information about health problems related to global warming?

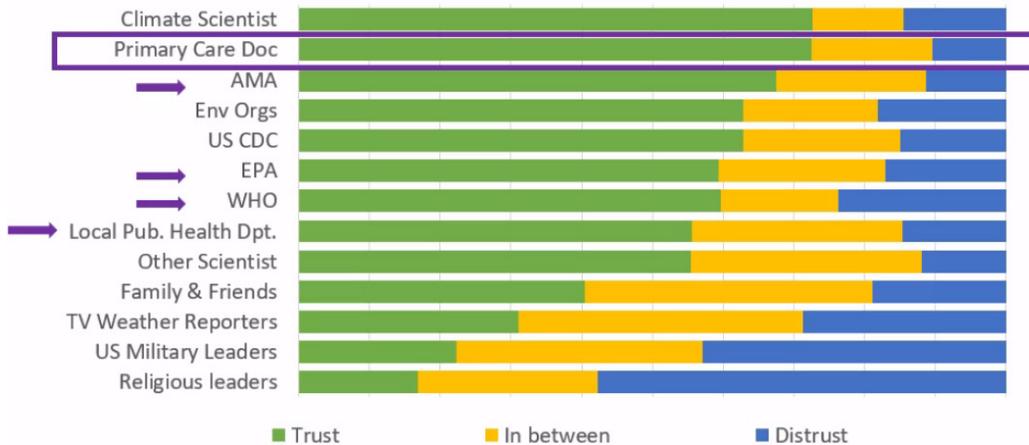


Figure 1. Trust and distrust of different information sources about climate change and health.

INFORMATION VALUATION CONCERNING DECISIONS MADE IN RESPONSE TO WILDLAND FIRES IN THE SOUTHWEST UNITED STATES

Previous qualitative empirical research suggested that fire managers used Decision Support Systems, not so much to support decision making, but rather to record and document support for decisions *after* they were made. Current quantitative analysis of primary data from western fire managers supports this previous qualitative evidence.

While fire managers consult a large number of internet data and information sources for management decisions, a relatively small number of sources are actually used. The same core sources are used across different time periods (e.g., prior to fire season and during fire season) and for different management decisions.



Photo by Dan Ferguson

SECTORAL IMPACTS OF DROUGHT AND CLIMATE CHANGE

Tourism and Recreation Sector: Declining lake levels are estimated to result in negative regional economic impacts ranging from \$3 million to \$16 million at Lake Mead and \$23 million to nearly \$30 million at Lake Powell, under various lake level scenarios. These impacts occur as a result of changes in visitation and total visitor spending. The losses in economic benefits to recreationists range from a low estimate of \$4.5 million at Lake Mead to a very high estimate of \$83.6 million at Lake Powell.

Duval, D., A. Bickel, G Frisvold. 2022. Effects of reservoir levels on Arizona national recreation area visitation, visitor spending, and local economies. *Journal of the American Water Resources Association* 58, 622–638.

Agriculture and Water Sector: A review of literature on the relationship between irrigation technologies, irrigation efficiency, and water consumption suggests that adoption of improved irrigation by itself, in many if not most cases, will not conserve water at the watershed or groundwater basin level. True water conservation requires efficiency

improvements to be combined with other institutional limits on water use. Policy implications are that (a) programs to encourage water conservation via improved irrigation technologies will fail except in special hydrological and institutional settings (b) to avoid such failure in Arizona, it is necessary to first identify where such settings exist.

Evidence supporting the widely held belief that improved efficiency conserves water is weak and mixed. Numerous studies demonstrate both theoretically and empirically that improving irrigation efficiency may not reduce water consumption and, in many cases, can actually increase it. Higher application efficiency means that crops take up a higher percentage of the water that is applied to them. But this means that less water is available to recharge aquifers or serve as return flows for downstream users. Increasing application efficiency at the farm-level can thus lead to more water use at that the basin- or watershed-scale.

CLIMAS PROGRAM EVALUATION AND LEARNING AGENDA

CLIMAS Investigators: A. Meadow, G. Owen

Additional Investigators: M. deBlois – Community Research, Evaluation, and Development, University of Arizona

Abstract: Transdisciplinary research, such as that done within the CLIMAS program, requires innovative evaluation to ensure that the research is robust, applicable to, and used by decision makers to increase resilience and improve well-being in our region. To connect science with decisions requires attention to the quality of engagement between researchers and societal partners—these relationships should be both substantive and equitable. And the outcome of these partnerships should be usable knowledge, as judged by those who need to use it.

CLIMAS has a tradition of using evaluation to gain insight into transdisciplinary and co-produced research. In our current funding cycle, we will enhance our evaluation and programmatic learning with a learning agenda. A learning agenda is a strategic plan an organization uses to build and use evidence in its decision-making surrounding both mission and operations. The goal of this process is to generate usable information and program-specific evidence about the effectiveness of our engagement, research, and capacity-building processes; progress toward our goals; and the societal impacts of our work.

We will conduct regular meetings with each CLIMAS project team to collaboratively develop theories of change, logic models, and actor maps to help assess progress and measure effectiveness. We will also conduct periodic interviews with CLIMAS project partners about evidence of impact and the research process.

A final CLIMAS impact report for the previous funding cycle will be available in fall 2023. This report contains data collected from annual reports and from periodic interviews with CLIMAS investigators (Fall 2019 and Winter 2022) and project partners (Spring 2022).

CLIMAS defines societal impacts as the ways that research, and the process of conducting research, influences the world beyond the academic realm. Societal impacts refer to the changes that research makes in the world, how, and for whom. We use the following seven categories of impact:

- **Instrumental applications**—tangible changes to plans, decisions, practices, or policies
- **Conceptual impacts**—changes in people’s knowledge about or awareness of an issue
- **Capacity building impacts**—enhancing the skills, expertise, or resources of an organization or group of people
- **Connectivity impacts**—new or strengthened relationships, partnerships, or networks that endure after a project ends
- **Attitudinal/cultural impacts**—changes to people’s attitudes toward or institutional culture around conducting transdisciplinary or engaged research
- **Social impacts**—changes to social systems that result from actions taken because of research
- **Environmental impacts**—changes to environmental systems that result from actions taken because of research

Our evaluation methodology is outlined in further detail in [Planning and Evaluating the Societal Impacts of Climate Change Research: A guidebook for natural and physical scientists looking to make a difference](#). The CLIMAS team also used this guide to embed societal impacts planning and documentation into our current grant, research projects, and approaches to engagement.

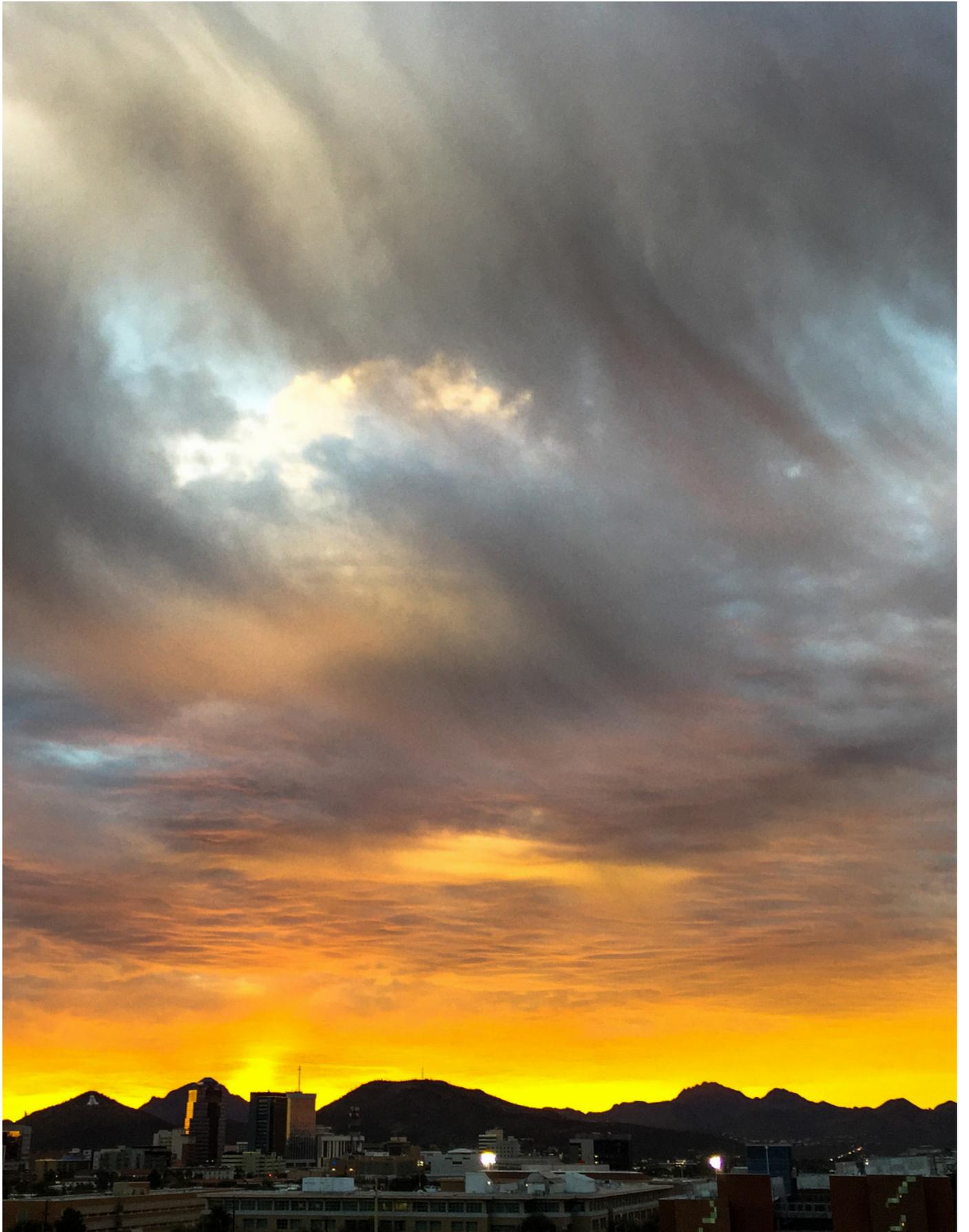


Photo by Dan Ferguson

EVIDENCE AND CASE STUDIES OF SOCIETAL IMPACT

COMMUNITY-BASED RESPONSES TO CLIMATE WATER CHALLENGES

Capacity Building: This project supports communities in Arizona and New Mexico as they grapple with understanding risks to their water supplies and evaluating strategies that can add resilience. As part of this work, a Community Drought Data Hub was developed on ArcGIS Online. From this platform, online visitors can link to three different Hub portals to access local and regional climate and water data for their community, as well as mapping and visualization tools to explore these resources. For rural communities in Arizona, drought planning data and research is far flung and difficult to interpret, especially without available staff capacity. These hub portals gather, filter, and visualize water and climate data that would otherwise require significant resources for a community to compile and interpret on their own.

Instrumental: The Community Drought Data Hub is being used by the Town of Superior to apply for funding from the Bureau of Reclamation WaterSMART Cooperative Watershed Management Program in summer 2023. The Data Hub will also be cited as part of a funding application to the Water Infrastructure Finance Authority of Arizona's Water Conservation Grant Fund in June 2023.

Capacity Building: Graduate students advised through this project have attained professional positions at: U.S. Bureau of Reclamation; Salt River Project; Resources for the Future; Montgomery and Associates; Arizona Municipal Water Users Association.

EVALUATING EXISTING AND DEVELOPING NEW DROUGHT INDICES USING MODELED SOIL MOISTURE TIME SERIES

Instrumental: This research developed a novel modeled soil moisture dataset for the Southwest and evaluated two commonly used drought indices. This work highlights how drought events at different soil depths are strongly related to seasonal patterns in precipitation and that drought index timescales should be optimized to follow these patterns. Results suggest how to best use drought indices for soil moisture monitoring across the Southwest. Results from this work have helped guide the selection of drought indices and optimal timescales for other drought monitoring projects including one with the US Forest Service.

Connectivity: The initial project study area focused on the Las Cienegas National Conservation Area in partnership with

the Nature Conservancy to examine longer-term drought impacts in this multi-use, Bureau of Land Management NCA. The study area has been extended to 240 study sites in four Major Land Use Areas (MLRAs—USDA Land Management Units) from southern New Mexico to southern California. These MLRAs represent a gradient in the seasonality of precipitation from summer dominated in southern NM to winter dominated in southern CA.

Capacity Building: Dr. Trevor McKellar gained invaluable experience in working with drought and climate data in the southwest U.S. and experience in working on engaged, applied climate research for his doctoral dissertation.

DEVELOPMENT OF A CUSTOM FIRE WEATHER MONITORING TOOL: THE SOUTHWEST BURN PERIOD TRACKER

Conceptual: This research and the Burn Period Tracker increases forecasters and fire managers awareness of how humidity changes throughout the day and to inform timing of management strategies. Typically, a large emphasis is placed on rainfall to contain wildfire, but relative humidity, timing, and burn period can also play a role in management. Fires can go out or stop spreading when it reaches a threshold of 20% humidity during the night, when there is no sun or heat.

Instrumental: The Burn Period Tracker was collaboratively developed by CLIMAS and SWGACC partners to show the number of hours per day when the relative humidity is above or below 20%. The Tracker is being used to inform wildfire management planning and decisions in Arizona and New Mexico and is now part of the fire SWCC fire danger intelligence page: https://gacc.nifc.gov/swcc/predictive/fuels_fire-danger/fuels_fire-danger.htm

ACTIVE AND COLLABORATIVE CLIMATE SERVICES: DEVELOPING CUSTOMIZED AND AUTOMATED CLIMATE REPORTS TO SUPPORT NATURAL RESOURCE MANAGEMENT AND PLANNING

Connectivity: A collaborative project with US Geological Survey to develop innovative climate services for land managers began in fall 2022 and led to a research partnership with the US Forest Service Kaibab National Forest (KNF). Land managers at KNF expressed the need for local drought and climate information provided in regular

updates. Our team developed a prototype automated climate report generator in fall 2022 that will continue to be developed in 2023. The prototype reports developed for this project led to a long-term partnership with US Forest Service land managers across Region 3 (AZ and NM) to develop custom climate services through 2027.

SECTORAL IMPACTS OF DROUGHT AND CLIMATE CHANGE

This project examines the impacts of drought and climate change on climate sensitive sectors in the Southwest, focusing on agriculture, outdoor recreation, and tourism.

Instrumental: In previous project years, extension reports were developed about drought and climate change. Santa Cruz County in southeast Arizona now requires entities that are soliciting county-funded grants to review these extension reports.

Summaries of research findings on relationships between drought and climate change on state park visitation and spending were used to develop the Arizona Parks & Trails 2023 Arizona Statewide Comprehensive Outdoor Recreation Plan. <https://azstateparks.com/scorp>

COMMUNITY CLIMATE PROFILES

This project addresses the lack of access to appropriate climate change information by producing climate profiles for communities to support their adaptation planning efforts.

Capacity Building: This project developed a successful model for providing communities with necessary information. Most of the profile reports done in this project have been used in some way by communities to support their own actions around climate change adaptation.

Conceptual: The profile report and related presentations about the profile for the Quad Cities area of Arizona, helped the Prescott City Council better understand the climate impacts their region is likely facing.

Instrumental: The climate profile for The Highlands at Dove Mountain, which was done at the scale of Pima County, was used extensively by consultants who developed the City of Tucson's Climate Action and Adaptation Plan (<https://climateaction.tucsonaz.gov/pages/caap>). The profile report was a major source of the climate science for Tucson's climate plan. The consultants accessed the report online.

BUILDING REGIONAL FOOD SYSTEM RESILIENCE IN SOUTHERN ARIZONA

In summer 2021, CLIMAS researchers partnered with the Pima County Food Alliance (PCFA), a food policy council in southern AZ, to gather more information about food system needs and opportunities through a series of focus groups, community conversations, and farmer interviews.

Instrumental: Findings from this research are being used to support policy changes to offer a reduced water rate for small, urban growers and food producers in Tucson, AZ. A report published in previous years was cited in a presentation to Tucson’s Mayor and Council in February 2023 and in negotiations with Tucson’s water utility. A lower

water rate would reduce costs and help increase small-scale farmers’ ability to sell their produce at a fair market value.

Capacity Building: This research supports the development of a community-based alliance around the local and regional food system in Pima County and southern Arizona. Findings are being used to revitalize and restructure the Pima County Food Alliance so that it can cultivate equitable food policy in the region, with attention to climate smart foodways, food access and distribution, workforce development, and land and water protection.



Photos Courtesy of Pima County Food Alliance

EDUCATION AND TRAINING

Capacity Building: Eight members of the CLIMAS team participated in the University of Arizona College of Law’s January in Tucson in 2023, which is a series of intensive education sessions that bring together distinguished faculty in the field of Indigenous governance and Indigenous rights to teach and hold discussions with Indigenous leaders, practitioners, and community members, as well as

other individuals interested in Indigenous affairs. CLIMAS participation in January in Tucson builds researchers’ capacity to engage ethically with Indigenous communities, communities at the frontlines of climate change, and underserved populations. It has led to the creation of an ethical engagement team that is working to develop guidelines and standard practices for CLIMAS.

CLIMAS EVALUATION AND LEARNING AGENDA

Instrumental: The societal impacts framework developed by A. Meadow and G. Owen—largely in part through the CLIMAS program evaluation—has been adopted by the Joint Fire Science Program (JFSP) to document the societal

impacts of their Fire Science Exchange Networks, and by the Arizona Institute for Resilience at the University of Arizona to develop a process to assess their societal impact.

POPULATIONS BENEFITED BY CLIMAS RESEARCH

Several CLIMAS projects and related efforts aim specifically to work in partnership with and provide information to communities across the Southwest:

- **Community-Based Responses to Climate Water Challenges:** This work aims to benefit rural areas in southern Arizona, including the Town of Superior, the Town of Patagonia, Queen Creek, and the City of Benson. Rural planners, administrators and elected officials often lack funding, staff and expertise with relevant data needed to conduct or apply climate and natural resources research and planning for their communities. The project provides small rural towns with drought response planning services and expertise that otherwise would not be accessible.
- **Information Valuation Concerning Decisions Made in Response to Wildland Fires in the Southwest United States:** Areas in the wildfire-urban interface in Arizona and New Mexico, and tribal communities in areas at risk from wildfire damage.
- **Sectoral Impacts of Drought and Climate Change:** This work supports agricultural and rural communities, particularly in Pinal, Cochise, and Yuma Counties in AZ.
- **Community Climate Profiles:** Profiles have been completed and used for rural and urban communities of Prescott, Yavapai County, Flagstaff, Oro Valley, The Highlands at Dove Mountain, Gila River Indian Community, Tucson, Prescott Valley, Chino Valley, Dewy-Humboldt, and Sedona in Arizona and Pueblo of Laguna, New Mexico.
- **Building Regional Food System Resilience in Southern Arizona – Learning from COVID- 19:** This work aims to benefit Pima County small-scale farms and food businesses, with specific focus on frontline and low-income communities in rural and urban areas.



Photo by Dan Ferguson

EDUCATION, TRAINING, AND WORKFORCE DEVELOPMENT

ENVIRONMENT & SOCIETY FELLOWSHIP PROGRAM

The [Environment & Society Fellowship](#) was created in 2013 by CLIMAS, with support from the University of Arizona Office of Research, Innovation, and Impact. The fellowship, managed by CLIMAS Investigators G. Owen and C. Greene, provides training and funding for graduate students to practice use-inspired research and science communication. Since its inception, the Fellowship program has funded 31 graduate students.

2022 Environment and Society Fellowship Projects

Julia Davies earned her PhD in Geography, Development, and the Environment in 2023. She investigated how low-income urban households in Zambia maintain food security amid persistent social and environmental challenges. As a CLIMAS Environment and Society Fellow, Julia has leveraged her dissertation research to develop two online webinars, two policy briefs, and one op-ed with her partners at the Zambia Agriculture Research Institute. She now is a research scientist in the Bureau of Applied Research in Anthropology at the University of Arizona. [Our cities are what we eat](#)

Jake Dean earned his Master's degree from the Center for Latin American Studies in 2023. He developed connections in an ejido in El Vizcaíno Biosphere Reserve to understand the socioecological and economic impacts of conservation development. Jake's research focused on the tensions between whale conservation and the fishing industry, the social ecology and conservation advocacy of the surrounding area, and the rise of the whale-watching ecotourism industry in Baja California. He is continuing this work as a PhD student and received an NSF Graduate Research Fellowship. [A Social Ecology of Whale-Watching Ecotourism in El Vizcaíno](#)

Rachel Zollinger is an interdisciplinary artist, educator, and PhD student in Art and Visual Culture Education. Her dissertation research investigates children's drawing practices as an expression of their ecological identities. Through this work, she aims to establish better understanding of how intertwining science practices, art cultures, and first-hand experiences with plants, animals, and places influence children's imaginative capacities. Her work is part of a broader, collaborative project with a science museum and local community partners in New Mexico to develop environmental education curriculum and teaching practices that support children's intellectual and emotional capacities to effectively respond to environmental issues. [Exploring Children's Drawing as Ecological Engagement](#)

Special Edition Southwest Climate Podcast — 2022 E&S Fellows: For this special edition of the Southwest Climate Podcast Gigi Owen sat down with the 2022 Environment & Society Fellows for a recap of their projects during their year as well as some words of wisdom for the incoming Fellows. <https://climas.arizona.edu/podcast/special-edition-sw-climate-podcast-2022-es-fellows>

2023 Environment and Society Fellowship Projects

[Rainfall variability, extreme events, and climate information in the Guatemalan Dry Corridor](#) — **Talia Anderson**, School of Geography, Development and Environment and the Laboratory of Tree Ring Research.

[Co-Producing Flood Justice in the Rio Grande Valley of Texas](#) — **Lucas Belury**, School of Geography, Development and Environment

[Pairing satellite-based maps of blue tarps with community data and stories to support just disaster recovery](#) — **Hannah Friedrich**, School of Geography, Development and Environment

[Diné Resource Governance: Early 20th Century Soil experiments in the Navajo Nation](#) — **Majerle Lister**, School of Geography, Development and Environment

GLOBAL CHANGE TOOLKIT AND THE TRANSDISCIPLINARY ENVIRONMENTAL SCIENCE FOR SOCIETY (TESS) PROFESSIONAL DEVELOPMENT PROGRAM

A gap exists between science and the needs of society to address complex environmental problems. Though many researchers want to see their work applied and decision makers want better access to scientific advances, higher educational systems traditionally have not trained students to work across these gaps. To address this shortcoming, we designed an online three-part online professional development series. Courses were offered throughout 2021 and 2022. These courses were then combined and re-designed for a 1-unit graduate course for the Global Change minor at UArizona.

Outputs

Curricula: 2022: Global Change 695G – Global Change Toolkit. Online Course. Effectively addressing global environmental change requires a toolkit of practical skills and strategies. Research approaches that engage directly with societal partners to address complex environmental problems will have the greatest impact and are the focus of this course. The course starts with an introduction to global environmental change problems, their characteristics, the reasons why collaborative research approaches are most

effective in addressing these problems, and what makes this type of research different from traditional academic research. It then addresses the concepts of positionality and trust before turning to practical aspects and skills for collaborative research including initiating and engaging partners, producing collaborative outputs. The course ends with a section on communication skills, including dialogue, for collaborative research addressing global environmental change problems.



Photo by Abhiant Tiwari

COMMUNITY SMALL GRANTS PROGRAM

In year two of the CLIMAS program, ITCA will begin to coordinate a community small grants program centered around pest management. This program intends to provide direct support to Indigenous communities in Arizona and New Mexico to work on this emergent and under-resourced climate and health challenge. Initial planning will include coordinating with the ITCA's Pesticide Program Manager to ensure environmental program needs are being addressed through the grant, drafting a community small grants application, obtaining legal review, and identifying effective strategies to engage communities that may benefit from the program.



Photo by Christina Greene

NEXT STEPS FOR 2023–2024

Over the next year, the four project teams—Heat, Aridity, Health, and Water Availability—will continue to build the relationships and conduct the scoping research needed to collaboratively design and implement their community-based projects. Through structured engagement processes across the region teams will learn from new and existing partners, document climate equity issues, and develop refined sets of research questions. Supported by the CLIMAS evaluation and learning agenda, we will continue to document our engagement and research development process. The Community Small Grants program will begin operation to support Indigenous communities to deal with climate and pest management issues.

In addition, two projects from the previous funding cycle aim to continue through the next year: a) Information Valuation Concerning Decisions Made in Response to Wildland Fires in the Southwest United States and b) Building Regional Food System Resilience in Southern Arizona. The partnerships and research needs developed through these projects have evolved and extended beyond the original scope of time outlined in the previous CLIMAS grant.



Photo Courtesy of Pima County Food Alliance

APPENDIX A: PUBLICATIONS 2022–2023

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APPENDIX B: CURRENT CLIMAS PROJECTS INDEX

The following projects are organized alphabetically by project lead investigator's last name.

* Denotes a project that began under the new CLIMAS grant in fall 2022.

IDENTIFYING GAPS IN STAKEHOLDER NEEDS REGARDING THE CLIMATE-HEALTH CONNECTION

CLIMAS Investigators: H. Brown, D. Ferguson, E. Austhof

Research Partners: Arizona Department of Health Services; AZ county health departments; Arizona State University

End Users: AZ county health departments; Arizona Department of Health Services, and other community groups across the country at the climate/health interface. Provide support for Pinal and Maricopa County's Implementation and Monitoring Strategies (IMS). Community organizations, non-profits, for-profit organizations, and vector control officials for distributing information to their members.

Additional Support: Arizona Department of Health Services; Climate and Health Adaptation Monitoring Program (CHAMP)

Abstract: As part of the Climate-Ready States and Cities Initiative, the CDC engaged 16 states and 2 large cities to implement a 5-step program Building Resilience Against Climate Effects (BRACE) in 2009. The program aimed to help communities prepare for the health effects of climate change. As BRACE ends, the CDC is now supporting the monitoring and evaluation of the efforts developed under BRACE: Climate and Health Adaptation Monitoring Program (CHAMP). To support these monitoring and evaluation efforts, we are working to map the Arizona network of climate/health advocates, to identify gaps that stakeholders need regarding the climate-health connection, and to develop strategies to better support these efforts. The goal of this project is to identify how academics working on climate and health issues can better serve the stakeholders who are actively working on climate/health adaptation planning. This information will help inform adaptation and mitigation plans for the state of Arizona and help build partnerships throughout the state with CLIMAS and other groups.

Findings: A national survey was distributed from June 14 to July 15, 2020 (n=200) and from July 15 to August 14, 2020 (n=300). Survey results suggest that when it comes to climate change and health information, respondents trust their primary care doctor or a climate scientist more than the Center for Disease Control, the Environmental Protection Agency, the World Health Organization, or even local health departments—all agencies that develop and distribute climate change and health information.

Outputs

Publications: Austhof, E., and H. Brown. 2022. Global warming's six MTurks: a secondary analysis of a US-based online crowdsourcing market. *International Journal of Environmental Research and Public Health* 19(14): 8320. <https://www.mdpi.com/1660-4601/19/14/8320/pdf>

Presentations: Climate Change and Health Lecture. College of Medicine, UArizona. March 2023

* CLIMATE AND HEALTH CORE, INITIAL PROJECT SCOPING

CLIMAS Investigators: H. Brown, E. Austhof, D. Ferguson,

End Users: City planners for green infrastructure; Wildfire managers and response teams; Pima County Health Department; Arizona Department of Health Services

Abstract: Human and animal health is affected by climate; however, it is not always explicitly recognized. The CLIMAS Climate and Health Core seeks to identify logical places to integrate health across the spectrum of climate resilience. So far, the core has identified policy around prescribed wildfire and green infrastructure as two areas of particular interest. However, the health implications are as yet under-explored. In year 1 of the project, we began a review to understand the landscape of these issues. Stakeholders from previous CLIMAS work (see project Identifying gaps in stakeholder needs regarding the climate-health connection) have indicated specific interest in health and wildfires.

Findings: As part of this scoping process, we merged data about monitoring trends in burn severity ([mtbs](#)) with the CDC/ATSDR's [Social Vulnerability Index \(SVI\)](#). Gross comparison indicates no difference between overall SVI between prescribed fires and wildfires for both AZ and NM. Data were restricted to the years 1987–2021 using point data by census tract SVI. If burns are happening in same census tract, it is not accounted for in this back of the envelope calculation.

COMMUNITY-BASED RESPONSES TO CLIMATE WATER CHALLENGES

CLIMAS Investigators: B. Colby, H. Hansen

Research Partners: A. Lien – School of Natural Resources and Environment, UArizona; A. Hullinger – Water Resource Research Center, UArizona; University of Nevada Reno; University of Colorado

End Users: U.S. Bureau of Reclamation; U.S. Department of Agriculture; Arizona Department of Water Resources; Central Arizona Project; Salt River Project; City of Benson; Town of Patagonia; Town of Superior; Flood & Flow Committee (Patagonia); Queen Creek Working Group (Superior); Planning and Zoning Commission (Benson); Sonoran Institute; The Nature Conservancy; Santa Cruz Watershed Collaborative

Additional Support: DOI Climate Adaptation Science Centers (CASC); DOI Landscape Conservation Cooperatives (LCC)

Abstract: This project examines community perceptions and decisions about climate science, economics, and policies associated with approaches designed to provide resilience in the face of increasing water scarcity in the Southwest. Strategies to be evaluated include investments in built infrastructure (e.g., reservoirs and pipelines), incentive-based risk-sharing agreements, watershed ecosystem services, and other forms of adaptation and mitigation. The project supports communities in Arizona and New Mexico as they grapple with understanding risks to their water supplies and evaluating strategies that can add resilience. The project emphasizes the role that ecosystem services in healthy watersheds can play in buffering water impacts of climate change, as well as the potential for climate mitigation as a strategy for communities in the southwest to use to enhance their water supply security. A main goal is to develop and demonstrate replicable method for co-producing resilient water-related community climate adaptation and mitigation strategies, including scientific and economic evaluation.

Outputs

Publications:

McGreal, B. and B. Colby. Effects of Economic and Climatic Factors on Arid Agricultural Water Use, *Journal of Soil and Water Conservation*. In press. Description: Central Arizona farmers respond to crop prices, federal programs and water costs when making water use decisions.

Colby, B. and H. Hansen 2022. Colorado Basin Incentive-Based Urban Water Policies: Review and Evaluation, *Journal of the American Water Resources Association*, Vol 55: 1098–1115. Description: Arizona urban water users respond to conservation incentives when making water use decisions.

Colby, B. 2023. Teaching Water Resource Economics for Policy Analysis, *Applied Economics Teaching Resources*. In press. Description: Water managers and stakeholders benefit from instruction in water resource economics.

Hansen, H. 2022. Climate, Prices, and Federal Programs: Choices for Irrigated Agriculture, MS Thesis. Department of Agricultural and Resource Economics, University of Arizona.

Newsletter: Hullinger, A. WRRC Getting Out in Arizona – Drought Planning in Patagonia. Weekly Wave e-digest distributed on March 31, 2023 to over 4,000 email recipients. Newsletter article describes how a collaborative Water RAPIDS team partnered with the Town of Patagonia to hold a Drought Planning Workshop and field trip in Patagonia, AZ. <https://wrrc.arizona.edu/news/wrrc-getting-out-arizona-drought-planning-patagonia>

Data: Community Drought Data Hub on ArcGIS Online. From this platform, online visitors can link to three different Hub portals to access local and regional climate and water data for their community, as well as mapping and visualization tools to explore these resources. Intended audience is stakeholders and decision-makers from rural communities in Arizona. For rural communities in Arizona, drought planning data and research is far flung and difficult to interpret, especially without available staff capacity. These hub portals gather, filter, and visualize water and climate data that would otherwise require significant resources for a community to compile and interpret on their own.

Community Engagement Workshops:

Drought Response Planning Workshop for Small Towns. October 19, 2022. Virtual. 24 local community leaders and natural resources managers attended from partner communities. Stakeholders need opportunities to share experiences and solutions with similarly situated peer networks. In this case, small rural communities are uniquely challenged by applying data scaled and interpreted for their drought planning uses. We shared initial data mining and policy inventories for the Town of Patagonia, City of Benson, and Town of Superior. Community partners were invited to engage with our team and invited speakers to evaluate drought vulnerability for your community and assess policies in response to climate threats.

Drought Response Planning Workshop for Town of Patagonia. March 22, 2023. Patagonia Public Library. 22 local leaders and community members attended and provided stakeholder input on the applicability of data and drought planning recommendations. The workshop goal was to prioritize and refine drought response options in consideration of baseline water supplies/demands, projections of climate impacts on those water supplies, and the range of risk factors identified in earlier stages of work.

Drought Response Planning Workshop for Town of Superior. March 27, 2023. Town Council Chambers of Town Hall. 16 local leaders, natural resources managers, and community members attended and provided stakeholder input on the applicability of the data and drought planning recommendations. The workshop goal was to collaboratively develop draft structure and key elements for the

proposal to create a Watershed Management Plan with recommendations from CLIMAS-funded drought resources for Town of Superior. Several workshop participants volunteered to participate in additional project-related efforts.

Engaging Rural Arizona Communities for Resilient Water Planning. August 15, 2022. Virtual. Hosted by Santa Cruz Watershed Collaborative. 18 natural resources managers, water planners, and watershed practitioners shared lessons and best practices that are not widely known about applying climate and water data for communities in rural Arizona. Enthusiastic questions about how their organization can implement similar data sharing practices.

Economic Incentives and Resilience in Western Water, INFEWS Workshop, November 11–12, 2022, Golden Colorado. 12 resource managers, researchers and outreach staff.

Presentations:

Water Limitations and How They Impact Us. August 2022. Phoenix, Arizona. Panel discussion with S. Porter (ASU), T. Davis (Agribusiness Water Council), and S. Smallhouse (Redington NRCD and Arizona Farm Bureau) hosted by Arizona's Conservation Districts Annual Conference. Over 200 agriculture professionals and water managers. Discussion of the water resources challenges and options that rural communities around dealing with climate change. Conversation with audience member about Willcox mountain front recharge options. <https://www.aacd1944.com/annual-conference>

Engaging Rural Arizona Communities for Resilient Water Solutions. March 2023. WRRC. University of Arizona ENVS 596B Guest Lecture to 17 students. Addressed methods, resources, and best practices of working with rural communities where water data is limited.

Replicable groundwater monitoring methods for rural Arizona. March 2023. University of Arizona Student Union Ballroom. Over 200 students and academic community. Data are lacking in many cases for rural parts of Arizona about the types of useful information that allows general monitoring of this resource over time, including depth to groundwater, well use by type, and limited pumping data. The methods are replicable for smaller communities that seek to independently assess available groundwater information for drought planning or other purposes, whereas accessing these data would be difficult to find and use otherwise.

Social Media: Newly completed resources are circulated on WRRC Twitter (1.4K Followers) and Facebook (1K followers) accounts.

Advisory Roles:

Colby, B: Arizona Land and Water Trust, advisor on water transactions management, 2020–2022; Arizona Nature Conservancy Board of Trustees, 2014–2022.

Hullinger, A. Santa Cruz Watershed Collaborative, member of Coordination Team and Restoring Flows and Floodplains Working Group, connecting watershed partnership lessons, needs, and resources from CLIMAS project areas, 2021-2022. Aravaipa Watershed Conservation Alliance, advisor and reviewer for their Watershed Management Plan, 2021–present. Town of Superior Queen Creek Working Group coordinator, assisting to connect watershed restoration goals with current science and policy options, 2021–present.

Lien, A. Board of Directors of the Arizona Section of the Society of Range Management. American Southwest Carbon Marketplace, focused on riparian restoration and carbon sequestration related to restoration projects.

Societal Impacts

Instrumental and Capacity Building: The Community Drought Data Hub is being used by the Town of Superior to apply for funding from the Bureau of Reclamation WaterSMART Cooperative Watershed Management Program in summer 2023.

The Data Hub will also be cited as part of a funding application to the Water Infrastructure Finance Authority of Arizona's Water Conservation Grant Fund in June 2023.

Capacity Building: Graduate students advised through this project include: Hannah Hansen, Agriculture & Resource Economics, August, 2022; Matt Ford, Hydrology, May, 2022; Mekha Pereira, Hydrology, May, 2022, and Zoey Reed-Spitzer, graduating May, 2024. Students that have been part of this work have attained professional positions at: U.S. Bureau of Reclamation; Salt River Project; Resources for the Future; Montgomery and Associates; Arizona Municipal Water Users Association

USDA LIVESTOCK FORAGE DISASTER PROGRAM AND RANCHING IN THE SOUTHWEST U.S.

CLIMAS Investigators: M. Crimmins, D. Ferguson, C. Greene, M. McClaran

Research Partners: National Weather Service; USDA Natural Resources Conservation Service; Farm Services Agency; Arizona Section of the Society for Range Management

End Users: Ranchers in Arizona and New Mexico, AZ and NM state drought monitoring committees, US Drought Monitor authors, regional drought monitoring experts

Additional Support: National Integrated Drought Information System (NIDIS)

Abstract: The 2014 Farm Bill permanently authorized the USDA Livestock Forage Program (LFP), which provides compensation to livestock producers who suffer grazing losses caused by drought and wildfires. The LFP bases payment eligibility on drought status categories of the U.S. Drought Monitor (USDM). Yet, there is evidence that USDM status assignments do not accurately capture the timescales of climate variability driving forage production and drought impacts across Arizona and New Mexico. Therefore, the current system may understate the extent of losses and need for compensation of Southwest ranchers. This study evaluates how the current application of the USDM in the USDA-LFP addresses drought and wildfire risks faced by Arizona and New Mexico ranchers and will seek out drought monitoring best practices specifically for rangeland systems.

Outputs

Publications: Forthcoming final report and peer-reviewed publication

EVALUATING EXISTING AND DEVELOPING NEW DROUGHT INDICES USING MODELED SOIL MOISTURE TIME SERIES

CLIMAS Investigators: M. Crimmins, D. Ferguson, T. McKellar, M. Schaap, C. Rasmussen

Research Partners: The Nature Conservancy

End Users: Land managers from USDA-Natural Resource Conservation Service, Bureau of Land Management, U.S. Forest Service; Drought monitoring committees, such as the AZ Governor's Drought Task Force, U.S. Drought Monitor. The project tracks drought on rangelands across Arizona and New Mexico constituting millions of acres of grazing lands. By presenting our results to these end users, we aim to strengthen the utility of existing drought monitoring.

Additional Support: National Integrated Drought Information System (NIDIS), NASA Space Grant Fellowship, USDA Southwest Climate Hub

Abstract: To assess the performance of simple drought indices like the SPI and PDSI relative to potential soil moisture regimes, we will use the 1D soil water model, HYDRUS to develop long-term (>50 years), daily resolution soil water profile climatologies for several locations across the Southwest to assess how seasonality and precipitation timing and frequency relate to monthly scale precipitation-based drought indices. Cross correlations and time series analyses will be used to assess when and where traditional drought indices align with modeled soil moisture stress. The modeling approach will also be used to assess the performance of temperature-based indices like the SPEI and further explore the role of increasing temperatures in driving drought stress across the region.

Findings: This research developed a novel modeled soil moisture dataset for the Southwest and evaluated two commonly used drought indices. This work highlights how drought events at different soil depths are strongly related to seasonal patterns in precipitation and that drought index timescales should be optimized to follow these patterns. Results suggest how to best use drought indices for soil moisture monitoring across the Southwest. Other key results include:

- The Standardized Precipitation Index was found to better represent soil water availability in soils of the semi-arid Southwestern United States.
- The relationship between meteorological index timescale and soil water depth operates roughly on a 1-month to 5cm step progression at shallow depths (<80cm).
- Analysis by soil type shows that clay loam soils produce shallower sloped timescale-depth relationships and higher correlations compared to sandy soils.

Outputs

Data: The full soil moisture dataset and driving meteorological data will be published on Zenodo in summer 2023 as part of the publication of several peer-reviewed manuscripts.

Publications: McKellar, T.M. 2022. Drought Monitoring in the Southwestern U.S.: Analysis of Seasonal Precipitation, Multiscalar Indices, and Soil Water. Department of Environmental Science, Ph.D. Dissertation. University of Arizona. <https://repository.arizona.edu/handle/10150/665665>

Presentations: How do multiscalar indices relate to soil water availability in the Southwest. Winter Meeting of the Arizona Section of the Society for Range Management. Maricopa, AZ, February 2023.

Societal Impacts

Capacity Building: Dr. Trevor McKellar gained invaluable experience in working with drought and climate data in the southwest U.S. and experience in working on engaged, applied climate research for his doctoral dissertation.

Instrumental: This research developed a novel modeled soil moisture dataset for the Southwest and evaluated two commonly used drought indices. Results suggest how to best use drought indices for soil moisture monitoring across the Southwest. Results from this work have helped guide the selection of drought indices and optimal timescales for other drought monitoring projects including one with the US Forest Service.

Connectivity: The initial project study area focused on the Las Cienegas National Conservation Area in partnership with the Nature Conservancy to examine longer-term drought impacts in this multi-use, Bureau of Land Management NCA. The study area has been extended to 240 study sites in four Major Land Use Areas (MLRAs – USDA Land Management Units) from southern New Mexico to southern California. These MLRAs represent a gradient in the seasonality of precipitation from summer dominated in southern NM to winter dominated in southern CA.

DEVELOPMENT OF A CUSTOM FIRE WEATHER MONITORING TOOL: THE SOUTHWEST BURN PERIOD TRACKER

CLIMAS Investigators: M. Crimmins, D. Ferguson, G. Frisvold, T. McKellar

Research Partners: C. Maxwell, National Interagency Fire Center – Southwest Coordination Center (NIFC-SWCC)

End Users: State, federal, and tribal wildfire managers working across the Southwest US

Abstract: A new monitoring tool developed in collaboration with the Southwest Coordination Center that provides access to an experimental fire weather monitoring product called the Burn Period Tracker. Burn period is defined as the number of hours per day where the hourly average relative humidity is less than or equal to 20% and is calculated at Remote Automated Weather Stations with real-time data and several years of historical data. Values range from 0 to 24 hours per day with higher values associated with increased fire danger. The tool is being used by fire managers across the Southwest and was identified as a need in a previously funded CLIMAS project focused on the value of weather and climate information for wildland fire managers.

Findings: Research on the regional relative humidity patterns and changes over time and relationships with past wildfire events is ongoing. This research informs the refinement and interpretation of the burn period tracker tool.

Outputs

Climate Service Tool: Burn Period Tracker <https://cals.arizona.edu/climate/SWBurnPeriod/>

Societal Impacts

Conceptual: This research and the Burn Period Tracker increases forecasters and fire managers awareness of how humidity changes throughout the day and to inform timing of management strategies. Typically, a large emphasis is placed on rainfall to contain wildfire, but relative humidity, timing, and burn period can also play a role in management. Fires can go out or stop spreading when it reaches a threshold of 20% humidity during the night, when there is no sun or heat.

Instrumental: The Burn Period Tracker is being used to inform wildfire management planning and decisions in Arizona and New Mexico and is now part of the fire SWCC fire danger intelligence page: https://gacc.nifc.gov/swcc/predictive/fuels_fire-danger/fuels_fire-danger.htm

* ACTIVE AND COLLABORATIVE CLIMATE SERVICES: DEVELOPING CUSTOMIZED AND AUTOMATED CLIMATE REPORTS TO SUPPORT NATURAL RESOURCE MANAGEMENT AND PLANNING

CLIMAS Investigators: M. Crimmins, T. McKellar

Research Partners: USDA – Forest Service, USDA – Natural Resources Conservation Service, Pima County – Natural Resources, Parks & Recreation

End Users: USFS Kaibab National Forest managers; National Forests across of AZ and NM; Land managers working with Pima County Department of Natural Resources and Parks; USDA- National Resource Conservation Service range conservation managers

Additional Support: DOI Climate Adaptation Science Centers (CASCs)

Abstract: A collaborative project with US Geological Survey to develop innovative climate services for land managers began in fall 2022 and led to a research partnership with the US Forest Service Kaibab National Forest (KNF). Land managers at KNF expressed the need for local drought and climate information provided in regular updates. Our team developed a prototype automated climate report generator in fall 2022 that will continue to be developed in 2023. This effort has developed into a long-term partnership with USFS land managers working across Region 3 (AZ and NM) to developing custom climate services through 2027. Other partners include Pima County Department of Natural Resources and Parks and the USDA-NRCS. This project has the potential to extend to other types of managers working across the southwest.

Outputs

Project Website and Reports: Five initial project reports from January–May 2023 are posted on a project website: <https://cals.arizona.edu/climate/reports/KNF/>

Presentations:

- Custom, automated climate reports for the Kaibab National Forest. USFS Kaibab National Forest All-hands Meeting. March 2023.
- Custom, automated climate reports for the Kaibab National Forest. USFS R3 Regional Meeting. April 2023.

New Funding Acquired: Developed contract with USFS for further development of reporting system (\$400K from 2023–2027).

Societal Impacts

Connectivity: The prototype reports developed for this project led to a long-term partnership with US Forest Service land managers across Region 3 (AZ and NM) to develop custom climate services through 2027.

SECTORAL IMPACTS OF DROUGHT AND CLIMATE CHANGE

CLIMAS Investigators: G. Frisvold, M. Crimmins

Research Partners: A. Bickel, D. Duval – Department of Agricultural and Resource Economics, UArizona

End Users: Arizona Parks and Trails; Arizona Department of Water Resources; Bureau of Reclamation; Central Arizona Project; Arizona Agri-Business and Water Council; Graham County; Greenlee County; Arizona Farm Bureau; Upper Gila Watershed Alliance

Populations Benefited: Rural areas of Cochise, Pinal, and Yuma Counties

Additional Support: Arizona Department of Water Resources; National Integrated Drought Information System (NIDIS); NOAA Regional Climate Centers (RCCs); USDA Climate Hubs; U.S. Geological Survey; Bureau of Reclamation; National Park Service; Arizona State Parks Board; Walton Family Foundation

Abstract: This project examines the impacts of drought and climate change on climate sensitive sectors in the Southwest, focusing on agriculture, outdoor recreation, and tourism.

Findings: Academics, governmental agencies, and non-governmental organizations have argued that adoption of more efficient irrigation technologies can encourage water conservation and aid in adaptation to drought and climate change. Improved efficiency can allow individual irrigators to lower water cost, raise yields, and increase profits. Yet, evidence supporting the widely held belief that improved efficiency conserves water is weak and mixed. Numerous studies demonstrate both theoretically and empirically that improving irrigation efficiency may not reduce water consumption and, in many cases, can actually increase it. Higher application efficiency means that crops take up a higher percentage of the water that is applied to them. But this means that less water is available to recharge aquifers or serve as return flows for downstream users. Increasing application efficiency at the farm-level can thus lead to more water use at that the basin- or watershed-scale.

This project reviewed literature on the relationship between irrigation technologies, irrigation efficiency, and water consumption. This included both economic, agricultural, and hydrological peer-reviewed literature and federal agency reports. A key insight from this literature is that adoption of improved irrigation by itself, in many if not most cases, will not conserve water at the watershed or groundwater basin level.

The literature review was used to identify cases where improved efficiency could lead to true water conservation. Another key insight is that true water conservation requires that efficiency improvements be combined with other institutional limits on water use. Policy implications are that (a) programs to encourage water conservation via improved irrigation technologies will fail except in special hydrological and institutional settings (b) to avoid such failure in Arizona, it is necessary to first identify where such settings exist.

Outputs

Publications:

G. Frisvold led the effort to organize publication of a Featured Collection on Severe Sustained Drought in the Colorado River Basin, published in the *Journal of the American Water Resources Association (JAWRA)*. The Featured Collection spanned three Academics, governmental agencies, and non-governmental organizations have argued that adoption of more efficient irrigation technologies can encourage water conservation and aid in adaptation to drought and climate change. Improved efficiency issues of the journal from 2022–2023. Peer reviewed articles for the collection included contributions from CLIMAS members B. Colby, C. Woodhouse, and G. Frisvold.

Duval, D., A. Bickel, G Frisvold. 2022. Effects of reservoir levels on Arizona national recreation area visitation, visitor spending, and local economies. *Journal of the American Water Resources Association* 58, 622–638. Selected findings: Declining lake levels are estimated to result in negative regional economic impacts ranging from \$3 million to \$16 million at Lake Mead and \$23 million to nearly \$30 million at Lake Powell, under various lake level scenarios. These impacts occur as a result of changes in visitation and total visitor spending. The losses in economic benefits to recreationists range from a low estimate of \$4.5 million at Lake Mead to a very high estimate of \$83.6 million at Lake Powell

Policy Briefings

Briefings on sectoral impacts of drought were given to:

- Denise Ross, Chief Data Scientist, White House Office of Science and Technology Policy
- University of Arizona President Robert C. Robbins' Presidential Advisory Commission on the Future of Agriculture and Food Production in a Drying Climate

Media Interviews:

[Cascading Colorado River cuts bring focus to future of Arizona agriculture](#). UANews. Jul 6, 2022

[Western farmers feeling weight of Colorado River water cuts](#). Agri-Pulse. Jul 27, 2022

[Not here for some agrarian fantasy](#). Arizona Public Media. Aug 1, 2022

['Basically what drives the economy right now': Nature-based work plays big role in Santa Cruz County](#). Arizona Republic. Aug 17, 2022

[The Colorado River drought is coming for your winter veggies](#). Vox. Aug 20, 2022

Societal Impacts

Instrumental: In previous project years, extension reports were developed about drought and climate change. Santa Cruz County in southeast Arizona now requires entities that are soliciting county-funded grants to review these extension reports.

Summaries of research findings on relationships between drought and climate change on state park visitation and spending were used to develop the Arizona Parks & Trails 2023 *Arizona Statewide Comprehensive Outdoor Recreation Plan*. <https://azstateparks.com/scorp>

INFORMATION VALUATION CONCERNING DECISIONS MADE IN RESPONSE TO WILDLAND FIRES IN THE SOUTHWEST UNITED STATES

CLIMAS Investigators: G. Frisvold, D. Ferguson, M. Crimmins, N. Zhang

Research Partners: C. Maxwell, National Interagency Fire Center – Southwest Coordination Center (NIFC-SWCC)

End Users: U.S. Forest Service; NOAA-National Weather Service; Bureau of Land Management; Bureau of Indian Affairs; National Park Service; Arizona Department of Forestry and Fire Management; New Mexico Forestry Division

Communities Benefited: Areas of the Wildland-Urban Interface in Arizona and New Mexico

Additional Support: NOAA National Weather Service (NWS); NOAA Regional Climate Services Directors (RCSDs); U.S. Forest Service; Bureau of Land Management; Bureau of Indian Affairs

Abstract: Several agencies have devoted substantial resources to develop data, outlooks, and decision support tools for fire management. Yet, there has been relatively little research done to assess how these have been used and how they improve fire management decisions. This study addresses two questions: how is climate information being used to inform wildland fire management decisions and what is the economic value of such information? Focus groups and an online survey of Southwest wildfire experts address the first question and form the basis of an economic analysis of the value of fire management information. This research seeks to reveal what opportunities exist to improve existing products and develop new ones.

We have collected primary survey data from a representative sample of roughly 200 fire managers from Arizona and New Mexico from federal and state agencies. This sample represents about 40% of all fire managers in the region. We are currently analyzing the data to understand managers' use of climate other data in decision making.

Findings: Previous research (by others) based on qualitative empirical methods suggests that Decision Support Systems (DSS) for fire management were being used—not so much to support decision making, but rather to record and document support for decisions after they were made. Analysis of primary data from western fire managers supports and quantifies this early finding.

While fire managers consult a large number of internet data and information sources for management decisions, a relatively small number of sources are actually used by many. The same core sources are used both across time (i.e. prior to vs. during fire season) and for different management decisions.

Data Management: We will be publishing descriptive and summary statistics from our survey in peer-review articles and extension reports. De-identified responses to protect anonymity of respondents will be available upon request as long requests are not for redundant activities or violate University rules governing privacy and data sovereignty.

Outputs

Data Tool: A new monitoring tool developed in collaboration with the Southwest Coordination Center that provides access to an experimental fire weather monitoring product called the Burn Period Tracker (<https://cals.arizona.edu/climate/SWBurnPeriod/>). This tool has now become operationalized and is being maintained by CLIMAS (see Development of a custom fire weather monitoring tool: the Southwest Burn Period Tracker).

AN ASSESSMENT OF DROUGHT AND CLIMATE VULNERABILITY AND RESILIENCE IN THE RIO GRANDE BASIN IN NEW MEXICO

CLIMAS Investigators: C. Greene, D. DuBois

Research Partners: A. Mangham, Senior Service Hydrologist, NOAA – National Weather Service End Users: New Mexico Drought Monitoring Working Group

Additional Support: National Integrated Drought Information System (NIDIS)

Abstract: This project assesses drought and climate vulnerabilities and resilience from the perspective of New Mexico residents and experts. The 2018 New Mexico Drought Plan calls for more in-depth assessments of New Mexico drought vulnerabilities and this project contributes to this need by identifying stakeholder concerns and drought research priorities along the Rio Grande Basin. This drought and climate vulnerability assessment engages with areas of concern identified by the New Mexico Drought Task Force, including water, economy, fire, recreation, health, agriculture, and the environment. This project provides an expansion of CLIMAS activities in New Mexico. With initial engagement with state officials, the NM Drought Task Force Team, and the NM Drought Monitoring Group, this project will expand CLIMAS's network of collaborators and stakeholders in New Mexico and identify emergent drought research priorities that feed into subsequent years of CLIMAS/NIDIS project work. A survey has been developed and is ready to be distributed to the working group.

* INCREASING ARIDITY AND IMPACTS TO RURAL LANDSCAPES ACROSS THE SOUTHWEST

CLIMAS Investigators: C. Greene, M. Crimmins, L. Prihodko, H. Geli, M. Meko

End Users: U.S. Forest Service; Bureau of Land Management; natural resource managers; local community wildfire planners and practitioners; communities creating new or updating Community Wildfire Protection Plans; rural community members living in wildfire risk areas

Abstract: Increasing aridity in the Southwest, along with factors such as insect outbreaks and fire suppression policies, is contributing to substantial increases in wildfires in the region. These large, high-severity fires impact livelihoods as well as the human health and well-being of rural communities. To better understand how increasing aridity is affecting wildfire across the Southwest, we will collaborate with stakeholders across the region to explore how changes in rural landscapes are impacting wildfire risk and events. Through this partnership, we aim to develop a shared understanding of 1) changes to wildfire in rural landscapes as experienced by rural communities and natural resource managers and captured through participatory action research that combines local social-ecological knowledge with analyses of remote sensing and climate data; and 2) the implications of those changes for the communities most impacted. Identifying trends in wildfire risk and impacts under increasing aridity will help rural communities and natural resource managers plan and advocate for a changing wildfire landscape.

This project also represents an important need as wildfire science and planning tends to focus on immediate wildfire response. Understanding the longer-term changing wildfire risk before a fire happens, as well as the long-term impacts of wildfire on rural communities after fires, remain a critical gap in wildfire knowledge. Engaged community research with communities pre- and post-fire is essential to informing wildfire planning and recovery.

* SUPPORTING HEAT RESILIENCE IN FRONTLINE COMMUNITIES

CLIMAS Investigators: L. Keith, H. Brown, B. McMahan, S. Smith

Research Partners: National Integrated Heat Health Information System (NIHHIS); Arizona Department of Health Services; Global Heat Health Information Network (GHHIN)

End Users: Local and state-level rural planners, housing and community development practitioners, emergency managers, hazard mitigation planners, and public health practitioners; federal initiatives such as the U.S. National Integrated Heat Health Information System

Abstract: Persistent and increasing chronic heat and extreme heat events present a complex challenge for communities in the U.S. Southwest. There is growing attention to urban heat resilience, how cities are addressing heat risk through heat mitigation strategies such as urban forestry and cool corridors, and heat management strategies, such as cooling centers. Less focus to date has been on how rural, tribal, and border communities, which face their own unique challenges and have different governance structures and resource availability, are being impacted by and can address increasing heat hazards. The objectives of this research are to better document the impact of heat on rural, tribal, and border communities; explore the current and emerging governance structures for rural heat resilience; and work with community partners on solutions to support increased rural heat resilience. A survey is in development about rural, tribal, and border heat resilience to be distributed in summer 2023.

Rural heat is understudied compared with urban heat, despite the fact that rural communities face unique challenges and often have less resources than cities. Rural populations also suffer from higher proportions of heat-related illnesses and deaths across the U.S. than urban populations.

COMMUNITY CLIMATE PROFILES

CLIMAS Investigators: A. Meadow, M. Crimmins, C. Woodhouse, L. Keith, H. Brown Research Partners: City of Prescott; Yavapai Climate Change Coalition

End Users: Prescott, AZ; Prescott Valley, AZ; Chino Valley, AZ; Dewey-Humboldt, AZ; Yavapai Climate Change Coalition; PROTECT campaign; Flagstaff, AZ; Tohono O’odham Nation – Office of Emergency Management; Town of Oro Valley – Office of Emergency Management; The Highlands at Dove Mountain; Pueblo of Laguna, NM; Verde Valley region - City of Sedona; Arizona Land and Water Trust

Populations Benefited: Prescott, AZ; Prescott Valley, AZ; Chino Valley, AZ; Dewey-Humboldt, AZ; Tucson, AZ

Additional Support: DOI Climate Adaptation Science Centers (CASCs)

Abstract: Climate change adaptation planning requires decision-makers to envision the future of their communities, and make well-grounded assumptions about economic, demographic, and cultural trends that are likely to affect that vision. However, many communities lack the technical resources to compile and analyze climate data and research findings, thus making the information essentially inaccessible to them. This project addresses the lack of access to appropriate climate change information by producing climate profiles for communities to support their adaptation planning efforts. These profiles include information such as historical/instrumental temperature and precipitation data from 1895 to present at a scale appropriate to the decisions made within the community of interest, explanations of key climate phenomenon that impact climate and weather in the region, current climate trends, projections of climate change for two RCPs (4.5 and 8.5), at a regional scale, and a summary of general regional climate impacts.

Climate profiles were completed for: City of Flagstaff, Tohono O’odham Nation, Town of Oro Valley, The Highlands at Dove Mountain, Pueblo of Laguna NM, City of Sedona, Arizona Land and Water Trust. After this project ended, the team was approached by PROTECT, a community group in Prescott to produce a climate profile for the City of Prescott. This final profile was completed in February 2023.

Findings: The process of generating climate profiles has revealed the extent to which communities—particularly smaller communities—are actively seeking guidance to inform their climate change adaptation decision-making. There is more demand than the team could fulfill with this project.

Outputs

Publications: Meadow, A., J. Weiss, M. Crimmins, and the Quad Cities Profile Working Group. 2023. Climate Profile for the Quad Cities Region of Arizona. Climate Assessment for the Southwest – University of Arizona. Description: This profile covers the geographic area of the Prescott Active Management Area and is aimed at the Quad Cities area of Arizona: Prescott, Prescott Valley, Chino Valley, and Dewey-Humboldt. The report will be used by the Yavapai Climate Change Coalition and PROTECT campaign in their work within the region to jump-start climate change adaptation planning.

Presentations:

CLIMAS Community Climate Profiles for Climate Change Adaptation Planning. Prescott City Council. April 2022.

Climate Change in the Quad Cities Region of Arizona. Prescott Area Wildland-Urban Interface Coalition. December 2022.

Climate Profile of the Quad Cities Region of Arizona. Prescott City Council. February 2023.

Project Website: Quad Cities Climate Collaborative – Climate Action Hub hosts a copy of the profile report and a list of adaptation recommendations that are based on some findings from the profile report: <https://yavapaiclimatcoalition.org/climate-action-hub>

Societal Impacts

Instrumental: The climate profile for The Highlands at Dove Mountain, which was done at the scale of Pima County, was used extensively by consultants who developed the City of Tucson’s Climate Action and Adaptation Plan (<https://climateaction.tucsonaz.gov/pages/caap>). The profile report was a major source of the climate science for Tucson’s climate plan. The consultants accessed the report online.

Capacity Building: This project developed a successful model for providing communities with necessary information. Most of the profile reports done in this project have been used in some way by communities to support their own actions around climate change adaptation.

Conceptual: The profile report and related presentations about the profile for the Quad Cities area of Arizona, helped the Prescott City Council better understand the climate impacts their region is likely facing.

* CLIMAS EVALUATION AND LEARNING AGENDA

CLIMAS Investigators: A. Meadow, G. Owen

End Users: CLIMAS team members; NOAA CAP/RISA programs

Abstract: Transdisciplinary research, such as that done within the CLIMAS program, requires innovative evaluation to ensure that the research is robust, applicable to, and used by decision makers to increase resilience and improve well-being in our region. To connect science with decisions requires attention to the quality of engagement between researchers and societal partners—these relationships should be both substantive and equitable. And the outcome of these partnerships should be usable knowledge, as judged by those who need to use it. CLIMAS has a tradition of using evaluation to gain insight into transdisciplinary and co-produced research. We will enhance our evaluation and programmatic learning with a learning agenda. A learning agenda is a strategic plan an organization uses to build and use evidence in its decision-making surrounding both mission and operations. The goal of this process is to generate usable information and program-specific evidence about the effectiveness of our engagement, research, and capacity-building processes; progress toward our goals; and the societal impacts of our work.

We will conduct regular meetings with each CLIMAS project team to collaboratively develop theories of change, logic models, and actor maps to help assess progress and measure effectiveness.

Societal Impact:

Instrumental: The societal impacts framework developed by A. Meadow and G. Owen—largely in part through the CLIMAS program evaluation—has been adopted by the Joint Fire Science Program (JFSP) to document the societal impacts of their Fire Science Exchange Networks, and by the Arizona Institute for Resilience at the University of Arizona to develop a process to assess their societal impact.

BUILDING REGIONAL FOOD SYSTEM RESILIENCE IN SOUTHERN ARIZONA

CLIMAS Investigators: G. Owen, K. Hamilton

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Research Partners: S. Thompson, Pima County Food Alliance and Arizona Food Systems Network

End Users: Pima County Food Alliance; University of Arizona – Center for Regional Food Systems; Arizona Food Systems Network; Community Food Bank of Southern Arizona

Populations Benefited: Tucson, AZ; Pima County, AZ

Additional Support: Community Food Bank of Southern Arizona; Pinnacle Prevention; Coverdell Fellows Program; Arizona Institute for Resilience

Abstract: From 2020 through spring 2021, this project documented the impacts of the COVID-19 pandemic in the local food system in Pima County, Arizona. The evolving crisis highlighted several long-standing issues in the local food system, including inequities in food access, food policy, food production and distribution, and food sovereignty. The crisis also revealed strengths in the local food system and opportunities to address these issues while building capacity and resilience. Our 2021 report synthesized people's experiences and lessons learned over the past year, in support of building a strong and equitable food system in southern Arizona that is resilient to future environmental, climate, economic, and health risks.

The next phase of research built on these findings through data collection, interviews, network building, and focus group discussions, including: a) analysis of cascading economic, climatic, and societal risks in the local food system over time; b) bolstering local partnerships between food businesses, organizations, and researchers; and c) developing a coordinated strategic plan for building local food system resilience and equity in the southern Arizona region in partnership with the Pima County Food Alliance.

Outputs

Publications:

Bellante, L., M. Carney, and G. Owen. 2022. Leveraging university resources to build awareness, support regional food policy, and disrupt dominant narratives guiding food-based development: Examples from University of Arizona's Center for Regional Food Studies. *Journal of Agriculture, Food Systems, and Community Development*, 11(3), 9–11. <https://doi.org/10.5304/jafscd.2022.113.017>

Pima County Food Alliance (PCFA) Actor Mapping Session Summary Report. March 2023. Prepared by Rachel Gildersleeve and Rachel Leih, Community Research, Evaluation, and Development (CRED) Team.

Interim Report – Update on methods, findings from pilot study, and evaluation process. Prepared by Anvi Bhakta. May 2023.

Community Engagement:

Community conversations held with eight organizations in Pima County's food system in March–June 2023. This effort is ongoing and will continue through December 2023. Participants ranged from 3–8 people in each focus group. The main point was to build relationships, hear about their role in the food system, ask about food related policy needs. Participants were people involved in food system organizations. Climate knowledge was relatively low among most. But high interest in how climate will affect the local food system. We collected exit survey responses. All are interested in continuing to work on the project or be informed of the work.

Participated in three public events hosted by other organizations in Pima County's Food System. Participants ranged from 20-50. Most of this effort was to spread word about the Pima County Food Alliance and encourage people to get involved. Methods to engage people included dot surveys, graffiti walls, and short surveys about food system issues/needs.

Presentations: February 2023 – Valuing Urban Farmers: How urban small farmers contribute to Tucson's resilience. Presentation to Tucson Mayor and Council. Tucson, AZ. Invited by Pima County Food Alliance, Community Food Bank of Southern AZ, Tucson Councilmember Dahl

Advisory Roles: G. Owen, Arizona Food Systems Network – Climate Smart Foodways Team (2021–Present)

Societal Impacts

Instrumental: Findings from this research were used to support policy changes to offer a reduced water rate for small, urban growers and food producers in Tucson, AZ. A report published in previous years was cited in a presentation to Tucson's Mayor and Council in February 2023 and in negotiations with Tucson's water utility. A lower water rate would reduce costs and help increase small-scale farmers' ability to sell their produce at a fair market value.

Capacity Building: **This research supports the development of a community-based alliance around the local and regional food system** in Pima County and southern Arizona. Findings are being used to revitalize and restructure the Pima County Food Alliance so that it can cultivate equitable food policy in the region, with attention to climate smart foodways, food access and distribution, workforce development, and land and water protection.

* CLIMAS TRAINING AND EDUCATION

CLIMAS Investigators: G. Owen, S. Carroll, D. Ferguson, C. Woodhouse, C. Greene, A. Meadow

End Users: CLIMAS team members; NOAA CAP-RISA programs; CLIMAS funded graduate students

Abstract: CLIMAS team members have developed collective expertise in the theory and practice of collaborative and ethical transdisciplinary research. We aim to continue building and evolving these skill sets within and beyond the CLIMAS team through a set of training initiatives and programs. CLIMAS training initiatives will fall under three main categories and be tailored to a variety of participants: 1) Collaborative and transdisciplinary research; 2) Ethical research collaborations with Indigenous peoples and frontline communities; 3) Societal impacts of climate-related research. This work also includes the Environment & Society Fellowship program, which funds up to four graduate students per year to conduct research projects in collaboration with community partners.

Outputs

Training: January in Tucson – eight members of the CLIMAS team participated in the University of Arizona College of Law's January in Tucson in 2023, which is a series of intensive education sessions that bring together distinguished faculty in the field of Indigenous governance and Indigenous rights to teach and hold discussions with Indigenous leaders, practitioners, and community members, as well as other individuals interested in Indigenous affairs. These interactive courses engage research and practice for the application of these topics in a variety of settings. CLIMAS participation in January in Tucson led to the creation of an ethical engagement team that is working to develop guidelines and standard practices for engaging ethically with Indigenous communities, communities at the frontlines of climate change, and underserved populations.

* NEW MEXICO CLIMATE RESILIENCE

CLIMAS Investigators: S. Reece, D. Ferguson, M. Meko, D. DuBois

Research Partners: State of New Mexico; Adaptation International; Groundwork Studio; Toole Design Group; KLA (Kim Lundgren Associates, Inc.)

End Users: State of New Mexico Departments and Agencies Populations Benefited: State of New Mexico

Additional Support: Federal Emergency Management Agency (FEMA)

Abstract: Through the Federal Emergency Management Agency Building Resilient Infrastructure and Communities (BRIC), a New Mexico Climate Adaptation and Resilience Planning grant was awarded to the State of New Mexico Energy, Minerals and Natural Resources Department (EMNRD) Energy Conservation and Management Division (ECMD). They are part of consulting team that will convene stakeholders to draft and finalize a statewide Climate Mitigation, Adaptation, and Resilience Plan. Stakeholders include state agencies, local and tribal governments, stakeholders in academia, industry, and non-government organizations. The plan will specify actions that individual agencies will take to a) mitigate climate related hazards and b) support other entities in the state to incorporate climate resilience and adaptation principles to enhance natural hazard mitigation planning and projects statewide. The statewide Plan (will be included as an annex in the update of the State Hazard Mitigation Plan, conducted by the New Mexico Department of Homeland Security and Emergency Management (DHSEM).

Outputs

Presentations: The Climate Challenges Facing the State. Climate Resilience Workshop, State of New Mexico. May 2023

* WATER AVAILABILITY

CLIMAS Investigators: C. Woodhouse, D. Ferguson, G. Owen, G. Frisvold, K. Jendrisak, M. Meko Research Partners: J. Fleck, University of New Mexico

Abstract: The overall goal of the Water Availability project is to investigate and clarify the understanding of the relationships between climate and streamflow at watershed scales that are meaningful to decision makers, primarily in northern New Mexico. Research evaluates these relationships over the last approximately 40-80 years, for which we have recorded climate and streamflow data, while also assessing changes in these relationships due to warming temperatures. This work also includes an assessment of changes in streamflow (e.g., changes in the timing of peak flow) over time. An overarching goal is to identify and provide data and/or information that is directly relevant to communities and other groups that may not have capacity or resources to conduct these kinds of analyses. Specifically, we hope to work with frontline communities including New Mexico Pueblos. Work with New Mexico Pueblo communities will be designed collaboratively with them to support their sovereignty, self-determination, and resource and data governance. We have set out to do a project that is as collaborative as possible, from determining the research questions, identification of watersheds of interest, and data to be used in analysis, to the analysis of results and dissemination of information.

This year, the team began background research on the cultural, political, economic, and legal contexts around water availability in the Rio Grande basin and connected with several researchers and stakeholders in that region.

Outputs

Presentations: EPA Creating Resilient Water Utilities – Train the Trainer. D. Ferguson. May 2023. Through the CLIMAS partnership with ITCA, the water team was invited to present climate resilience to trainers for the U.S. EPA's Creating Resilient Water Utilities (CRWU) program. There were approximately 20 people in attendance. Training focused on water utilities for all of Indian Country in EPA Regions 5 through 10. The presentation provided an overview of each of those 6 EPA regions in terms of climate impacts and how they differ across those regions.

