



CLIMAS

Climate Assessment for the Southwest
A NOAA RISA TEAM

Collaboratively Assessing Critical Social-Ecological System Buffers to Help Build Regional Climate Resilience

PROGRESS REPORT:

June 1, 2021 — May 31, 2022

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Contact:

Daniel Ferguson, Director, Climate Assessment for the Southwest
Arizona Institutes for Resilience |
University of Arizona | ENR2 Building |
1064 E. Lowell St. | Tucson, AZ 85721
dferg@arizona.edu | (520) 626-1779 | climas.arizona.edu

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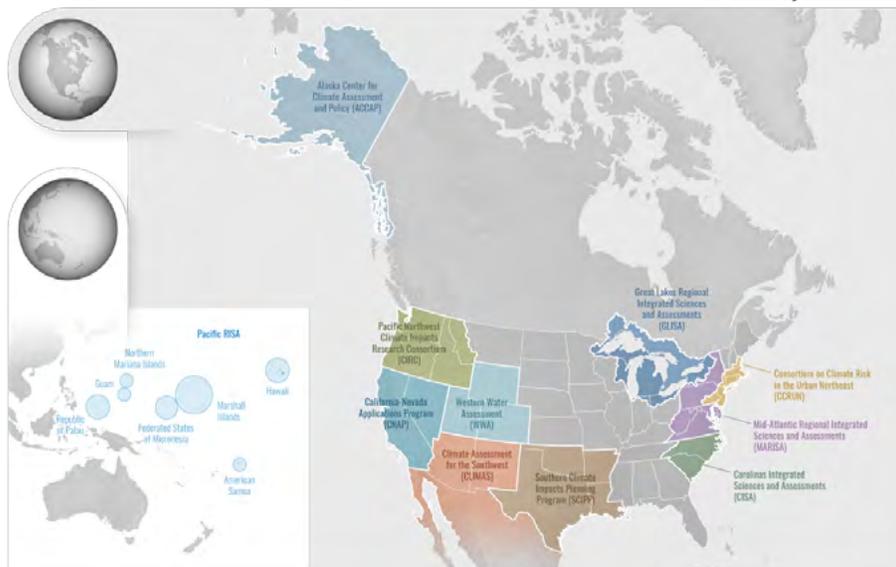




What is CLIMAS?

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

Currently funded RISAs



2021 – 2022 CLIMAS Research Team

Principal Investigators:

Daniel Ferguson – CLIMAS Lead Investigator and Director; Assistant Professor, Department of Environmental Science; UArizona

Heidi Brown – Associate Professor, College of Public Health, UArizona

Michael Crimmins – Professor & Extension Specialist - Climate Science; Department of Environmental Science, UArizona

George Frisvold – Professor, Agricultural and Resource Economics, UArizona

Connie Woodhouse – Professor, Geography, Development, & Environment, UArizona

Co-Principal Investigators:

Stephanie Carroll – Assistant Professor, Public Health Policy and Management, UArizona

Bonnie Colby – Professor, Agricultural and Resource Economics, UArizona

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

Ladd Keith – Assistant Professor, School of Landscape Architecture & Planning, UArizona

Ben McMahan – Assistant Research Professor, AZ Institutes for Resilient Environments & Societies, UArizona

Alison Meadow – Associate Research Professor, AZ Institutes for Resilient Environments & Societies, UArizona

Gigi Owen – Assistant Staff Scientist, AZ Institutes for Resilient Environments & Societies, UArizona

Jeremy Weiss – Climate and Geospatial Extension Scientist, School of Natural Resources and the Environment, UArizona

Senior Personnel:

Erika Austhof – Research Specialist, College of Public Health, UArizona

Christina Greene – Assistant Research Scientist, CLIMAS, UArizona

Mitch McClaran – Professor, School of Natural Resources and the Environment, UArizona

Craig Rasmussen – Professor, Soil Water & Environmental Science, UArizona

Marcel Schaap – Associate Professor, Soil, Water and Environmental Science, UArizona

Margaret Wilder – Associate

Professor, School of Geography and Development, UArizona

Research Affiliates:

Ashley Bickel – Economic Impact Analyst, Agricultural and Resource Economics, UArizona

Michael DeAntonio – Research Scientist, New Mexico State University

Madeleine deBlois* – Research Scientist, Community Research, Evaluation & Development, UArizona

Dari Duval – Economic Impact Analyst, Agricultural and Resource Economics, UArizona

Stan Engle – Research Staff, New Mexico State University

Andrea Gerlak – Director, Udall Center - Studies in Public Policy, UArizona

Rey Granillo – Development and Information Technology, AZ Institutes for Resilient Environments & Societies, UArizona

Zack Guido – Assistant Research Professor, AZ Institutes for Resilient Environments & Societies, UArizona

Ashley Hullinger* – Research Scientist, Water Resources Research Center, UArizona

Sarah Leroy – Research Staff, AZ Institutes for Resilient Environments & Societies, UArizona

Aaron Lien* – *Assistant Professor*, School of Natural Resources and the Environment, UArizona

Graduate and Undergraduate Student Researchers:

Antonio Arredondo, Tye Bell*, Benni Delgado, Chris Destiche*, Taylor Dew*, Jennie Doss, Ramon Driesen, Matthew Ford*, Natalie Franco*, Hannah Hansen, Mau Herrera, Dharma Hoy, Surabhi Karambelkar, Eden Kinkaid, CJ Larsen, Jace LeBlanc*, Trevor McKellar, Madeline Moeller, Mekha Pereira*, Leslie Pilli, Sarah Renkert*, Erika Schmidt, Danielle Tadych*, Wenting Zheng*

Environment & Society Fellows:

2021 – **Lea Schram von Haupt, Bailey Stephenson, Simone Williams**

2022 – **Julia Davies*, Jake Dean*, Rachel Zollinger***

* New additions to the CLIMAS team during the reporting period.

CLIMAS by the Numbers

97 Presentations Given to Stakeholder & Academic Audiences



83 Appearances in the Media 

6576 CLIMAS-related Twitter Followers 

15 Advisory Roles Served 

21 Academic Articles Published 

10 Workshops, Seminars, & Trainings Facilitated

17 Related New Proposals Funded 

12 Podcasts Recorded 

30 Climate Briefings Disseminated 

8 Research Reports & Briefings Written 

4 Master's Theses Completed 

Selected Research Findings and Highlights



Photo credit NOAA Unsplash

Identifying Gaps in Stakeholder Needs Regarding the Climate-Health Connection

In January 2021, we conducted key informant interviews among BRACE recipients to understand how health departments responded to the dual hazards of Heat Related Illness (HRI) and COVID-19. Health jurisdictions who worked in both heat preparedness and on the COVID-19 response highlighted three themes to maintain the public health capacity throughout the pandemic: 1) adapting to changing roles and responsibilities; 2) building and strengthening inter-organizational partnerships; and 3) maintaining flexibility through cross-disciplinary training. With impending impacts of a changing climate and extreme events with subsequent public health impacts, responses that meet dual purposes are necessary.

Austhof, E. and H.E. Brown, 2021. *Flexibility and partnerships perceived as supportive of dual hazard response: COVID-19 and Heat Related Illness, Summer 2020. Journal of Climate Change and Health 4:100068. doi:10.1016/j.joclim.2021.100068*

Is Adaptation Maladaptation? An assessment of mosquitoes and water harvesting

Well-maintained green infrastructure design strategies have the greatest impact on conservation while limiting the negative consequences of mosquitoes. If green infrastructure is to be used as an adaptation technique, then it is important to understand when it works best. In this study, undergraduate researchers visited green stormwater infrastructure sites after a rain event to check for water and mosquitoes. One large basin near a parking garage was positive for mosquito larval and failed to drain even after 9 days.

Brown, H.E., L. Keith, V. Madera-Garcia, A. Taylor, N.

Ramirez, and I. Ogata. 2022. *Greening up for mosquitoes: A comparison of green stormwater infrastructure in a semi-arid region. Journal of the American Mosquito Control Association 38(2):109-112. Addresses need to understand potential downsides of poorly designed or maintained green infrastructure. Written in collaboration with community partners from Tucson Water and Pima County Vector Control. <https://doi.org/10.2987/21-7055>*

Community-Based Responses to Climate Water Challenges

This study explored how the type of water source (e.g., groundwater or local/imported surface water) and groundwater regulations have influenced historical cropping patterns across Arizona. By comparing unregulated and regulated groundwater areas, the study finds that irrigated acres are increasing in unregulated regions while decreasing in regulated regions. Groundwater dominated parts of the state are experiencing increases in acreage of high water use crops, while surface water dominated regions have growing acres of low water use crops.

Ford, M. 2022. Connections Between Cropping Trends, Water Availability, and Groundwater Regulations. M.S. Thesis. UArizona Hydrology & Atmospheric Sciences.

This study explored statistical relationships between groundwater levels and economic and climatic variables in two rural basins in southeastern Arizona. A depth-to-water metric is significantly related to non-exempt wells, housing units, per capita income, and planted acreage. Well installation is strongly related to developed acreage, suggesting that development patterns, not crop irrigation, are most strongly linked to groundwater declines.

Pereira, M. 2022. Statistical Relationships Between Groundwater, Climatic, and Economic Factors in Southeastern Arizona. M.S. Thesis. UArizona Hydrology & Atmospheric Sciences.

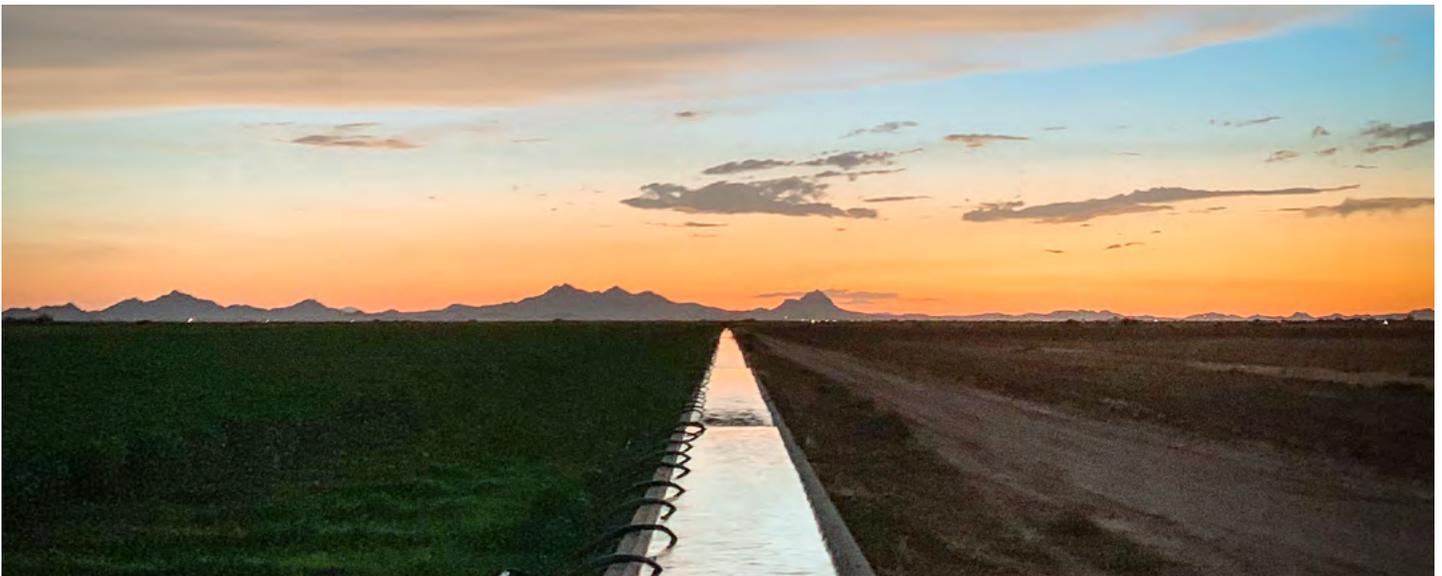


Photo credit Frankie Lopez Unsplash

Impacts of Climate Extremes to Interstate and Local Trucking Industry across NM and AZ

Convective dust events can occur without much warning and cause as much or in some case more damage than spring synoptic storms that last a full day. The convective dust events are triggered by thunderstorms and can pop up quickly depending on amount of atmospheric moisture, stability of the atmosphere, temperature, sunlight, and winds. Based on satellite observations, summertime convection often occurs over the Gila or Chiricahua Mountains and can spark growth of storms by upslope forced convection. We successfully demonstrated the use of inexpensive time-lapse cameras to assess dust events. Observations included the very fast evaporation and movement of water by wind.

Observations of the dust emissions show complexity and the importance of vertical motion and convection in the dispersion of dust plumes. One of the difficulties in using this method was the level of effort to extract the dust events from the images. We explored the use of machine learning to examine the images during a short pilot project and the method proved successful.

DuBois, D. 2022. Dust Mitigation Monitoring Project, Final Report. Prepared for NMDOT Research Bureau. Prepared by New Mexico State University, Department of Plant and Environmental Sciences.

Adaptation to Climate Variability and Change: Markets, Policy, Technology, and Information

Santa Cruz County's Nature Base Restorative Economy (NBRE), which includes nature-based industries, such as agriculture, nature-based tourism, and environmental conservation and restoration activities, contributes more than \$121 million in county sales and 1,200 jobs. Opportunities to expand nature-based tourism can be furthered by investments to improve tourism infrastructure, such as lodging and other amenities. Opportunities exist to help protect and preserve working landscapes through successional planning for ranchers and support for future generations of farmers and ranchers in the county.

Flood control is a major consideration in the county, particularly in the Nogales area. Ongoing investment in infrastructure for flood control represents an opportunity to apply principles of conservation and restoration to such projects, enabling co-benefits such as habitat creation, revegetation, and groundwater recharge.

Duval, D., A.K. Bickel, G.Frisvold, W. Zheng. 2021. *The Nature-Based Restorative Economy (NBRE) in Santa Cruz County, Arizona. Department of Agricultural and Resource Economics, University of Arizona, Cooperative Extension. Tucson, AZ.*



Photo credit Frankie Lopez Unsplash

Information Valuation Concerning Decisions Made in Response to Wildland Fires in the Southwest United States

The Wildfire Decision Support System (WFDSS) is intended to assist “fire managers and analysts in making strategic and tactical decisions for fire incidents.” Previous qualitative research suggests that WFDSS is used more for documenting and justifying decisions after they are made than for making initial decisions. Our quantitative survey supports and reinforces this earlier finding. 58% of respondents said they agreed or strongly agreed that they use WFDSS primarily to document, rather than inform, decisions. A third of respondents agreed or strongly agreed that they used WFDSS to inform their decisions prior to making them. WFDSS received relatively higher marks among respondents as a means of organizing data and documenting decision. Of respondents, 87% found WFDSS somewhat or very helpful at documenting fire management decisions. More than 85% found WFDSS somewhat or very helpful for aggregating data, visualizing data, and understanding values at risk. Although average relative humidity has not been much used in previous studies predicting fire size and suppression costs, for Arizona it was found to be a significant negative predictor of both suppression costs and of very large fires. Many studies estimate the determinants of fire size and suppression costs evaluating data *ex post*. This study attempts to improve *prediction* of large fires.

Dew, T.J. 2021. [It is a Dry Heat: Econometric Model of Historic Fires](#). M.S. Thesis, Department of Agricultural & Resource Economics, University of Arizona.

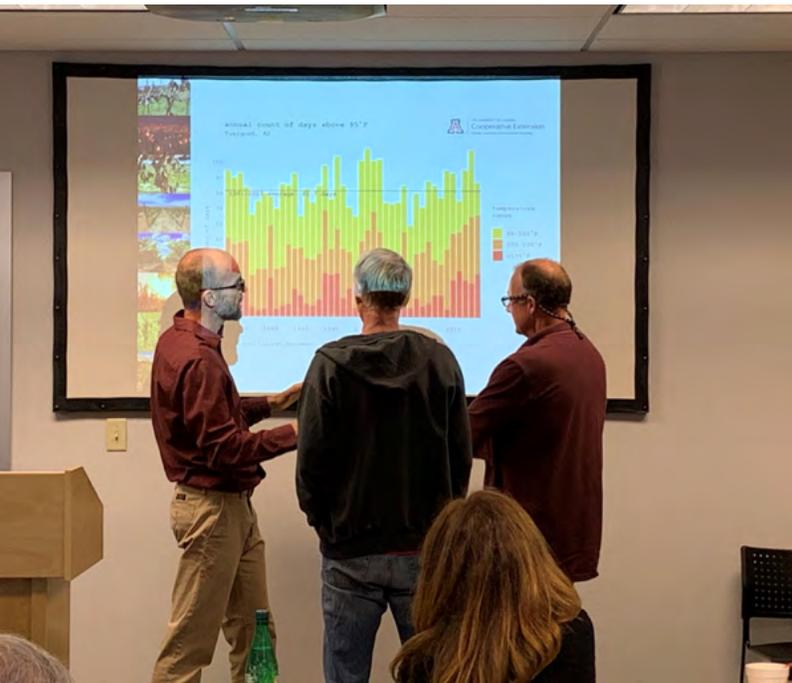


Photo credit by Jeremy Weiss

Sectoral Impacts of Drought and Climate Change

For cropland production in Arizona, which is virtually all irrigated, the effects of drought on crop production are quite different from those in the major agricultural production regions of the Plains and Midwest. In those areas, which are largely rainfed production, drought has significant negative effects on crop yields. In Arizona, drought has little effect on crop yields. Drought primarily affects acreage planted. If farmers have insufficient irrigation water supplies, they cut back acreage, but yields on remaining planted acres remain relatively stable. In Arizona, the main impacts of drought are from longer-term, hydrologic drought causing acreage reductions, rather than short-term drought affecting yields.

Bickel, A.K., D. Duval, G. Frisvold. 2021. Drought and Agriculture in Arizona. Final Report to the Arizona Department of Water Resources. University of Arizona Cooperative Extension.

The effect of drought on outdoor recreation depends on the length of the drought measure. Short-term drought as measured by the one-month Standard Precipitation Index (SPI) is positively associated with visits, while longer-term drought as measured by the 24-month Standard Precipitation Index (SPI) is negatively associated with visits. People may avoid or delay outdoor recreation in especially rainy months (short-term effect). Longer term drought can reduce streamflow, water in seeps in springs, and wildlife viewing opportunities, while increasing wildfire related park closures.

Duval, D., A.K. Bickel, and G. Frisvold. 2021. Effects of Reservoir Levels on Arizona National Recreation Area Visitation, Visitor Spending, and Local Economies. Journal of the American Water Resources Association. JAWR-21-0052-P.



Photo credit Melissa Merrick

Visualization & Analysis Tools for the North American Monsoon – Integrating Citizen Science Data and Observations

As generally assumed, the monsoon is highly variable across even small geographic areas, like Tucson metro area and Pima county. The data and visualizations derived from this project illustrate this variability on a daily/event basis and inform seasonal monsoon tracking that considers how these variations play out in small regions. The station data is facilitating a grid (MRMS/PRISM) vs. station data analysis of daily precipitation totals to highlight this variability and assess the correspondence and accuracy between station observations and grid-based estimates.

The Influence of Climate on Lower Colorado Streamflow Variability: Present, Past, and Future

This research investigates the climatic controls on the Gila River and its major tributaries, the Verde and Salt Rivers, to gain insights on how trends in climate may impact future water supply. No significant decreasing trends in annual streamflow in the upper Gila, Salt and Verde Rivers are evident despite warming temperatures, although decreases are evident in autumn and spring streamflow. While cool season precipitation is the most important climatic variable for annual streamflow, summer temperatures are also important, and the influence of monsoon precipitation is also discernable in certain years.

Woodhouse, C.A. and B. Udall. 2022. Arid land rivers in a changing climate. Earth Interactions 26:1-14. <https://doi.org/10.1175/EI-D-21-0014.1>

Featured Accomplishment

During the current reporting period, the fifth year of the current CLIMAS proposal, researchers produced and delivered tailored products that are useful for our research partners and end users. These products were used to advance adaptive capacity, policy initiatives, and decision-making. Our top accomplishment this year is represented by the depth and breadth of partnerships we have developed across sectors, disciplines, and climate issues in the Southwest. As part of our evaluation efforts, we conducted interviews with 14 CLIMAS project partners. All partners we reached out to responded to the interview invitation enthusiastically and wanted to participate. Their reflections on the research process provided crucial insight about how they were using information and research findings in their operations and decision making. We will take these lessons learned and apply them to our revamped learning agenda and evaluation process for CLIMAS's next phase. See **Evidence and Case Studies of Societal Impact** for more details.

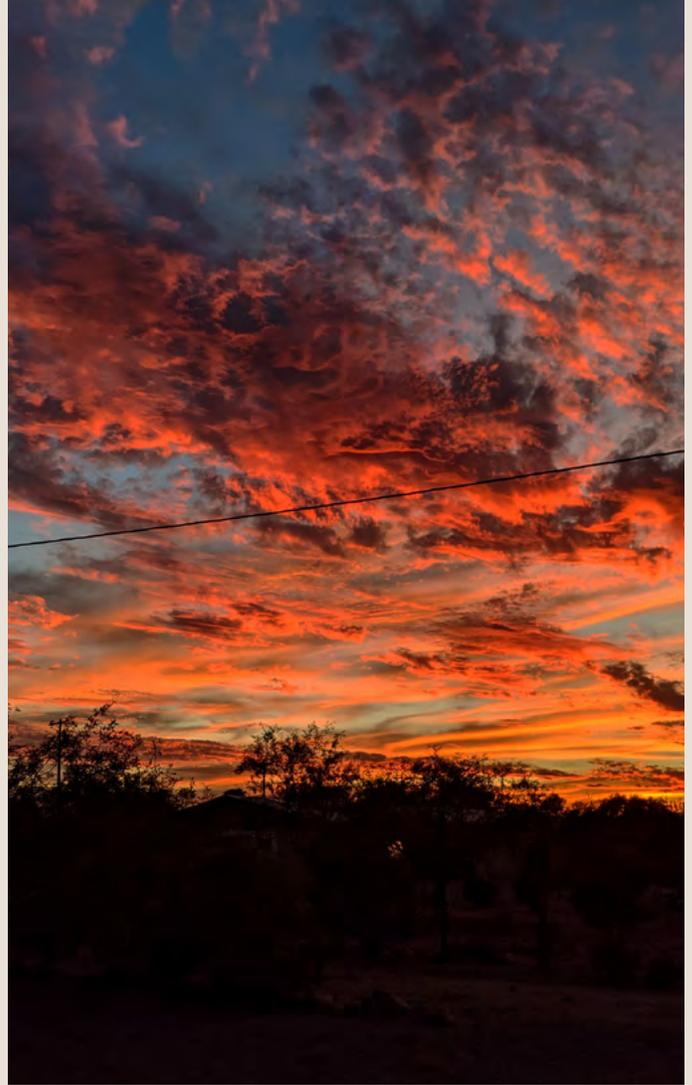


Photo credit Dan Ferguson

New Areas of Focus or Partnership

As we developed our proposal for the next phase of CLIMAS, we examined ways to expand the reach and scope of our work. We seek to develop connections with new community partners to inform local and regional challenges. Over the past year, we strengthened relationships with researchers in New Mexico and with the Inter-Tribal Council of Arizona (ITCA). Two new co-principal investigators from New Mexico and one new principal investigator from ITCA will join the CLIMAS team for the next phase of our program. We also established connections with the New Mexico Tribal Resilience Action Network, who is interested in partnering during our next phase.



Photo credit Dan Ferguson

Outreach and Engagement

CLIMAS outreach and engagement occurred mostly virtually during this reporting period due to COVID-19 related restrictions. CLIMAS researchers gave presentations, hosted workshops, and used several online communication tools such as newsletters, data hubs, and interactive websites.

Newsletters:

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. Twelve issues were distributed between June 2021 through May 2022. Issues about the summer monsoon and heat (May, July, and August) had the highest number of viewers. climas.arizona.edu/swco

Rainlog.org Monthly Climate Summary Email Newsletter.

M. Crimmins authored and sent twelve newsletter issues between June 2021 – May 2022 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. Twelve episodes aired between June 2021 through May 2022. The top episodes aired in July, August, and October 2021, about the monsoon and ENSO patterns.

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 Twitter. David DuBois continued his use of Twitter via the NM Climate Center account (@nmclimate). This account had 3085 followers as of June 2021. 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.

CLIMAS Twitter. The CLIMAS program's Twitter account (@CLIMAS-UA) has 991 followers as of June 2022. Posts that generated the highest amount of interest were related to the summer monsoon, the Southwest Climate Podcast, advertising TESS a CLIMAS-affiliated online course (Transdisciplinary Environmental Science for Society), and winter precipitation.

CLIMAS PI M. Crimmins (@mike_crimmins) posts on climate conditions, drought impacts, tools/information and retweeting CLIMAS products like SWCO and podcast. He has 987 followers and posted about 100 tweets over past year.

CLIMAS PI L. Keith (@laddkeith) posts about extreme heat conditions, urban planning, and climate change in the southwest. He has 1513 followers and posts regularly.



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](#)

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. Bets are currently underway for the 2022 monsoon season.

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.



Photo credit Dan Ferguson

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.

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.

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.



Photo credit Ben McMahan



Photo credit Robert Murray Unsplash

Workshops and Seminars:

NMSUCCESS NMSU Climate Change Education Seminar

Series: D. DuBois assisted in four online, public presentations for this seminar series. The speakers invited to speak this year addressed climate anxiety, climate change poetry, impacts of climate change to water, renewable energy, and visual storytelling. Attendance ranged from 30-60 people at each event. Local staff from Senator Ben Ray Lujan's office continue to support the seminar series and provide input on speakers, scheduling, marketing, and operations.

Academy for Learning in Retirement Workshop Series:

This workshop aimed to increase climate knowledge among retirees. It occurred in weekly sessions throughout May 2022. Approximately 35 people attended the four-part workshop.

American Society of Adaptation Professionals – Private Sector Climate Service Provider Academy:

B. McMahan helped ASAP organize a multi-day workshop for adaptation professionals in Fall 2021. He was on the organizing committee and developed content about the Southwest for the workshop. Attended by approximately 50 people

Transdisciplinary Environmental Science for Society

(TESS): C. Woodhouse, D. Ferguson, and G. Owen developed three 4-week online courses for students and professionals to learn about collaborative transdisciplinary research. The three courses were: 1. Fundamentals of Transdisciplinary Research; 2. Practicing Collaborative Research; 3. Communication Strategies for Collaboration. Courses were offered throughout 2021 and 2022.



Photo credit Carol Lee Unsplash

Other Outreach:

H. Brown and colleague J. Jernberg launched a Climate Champions in Health program to recognize the climate work done by health providers in Pima County. It mirrors a successful program in Maricopa County, AZ

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:



Photo credit Dan Ferguson

- **Identifying Gaps in Stakeholder Needs Regarding the Climate and Health Connection:** Maps of Cooling Centers in Tucson are used by [Pima Association of Governments \(Pima County\)](#), Tucson Pima Collaboration to End Homelessness, and Chicanos Por La Causa. This information aims to benefit populations that experience high exposure to heat stress Pima County, including homeless populations and people without cooling systems in their homes.
- **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, 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.
- **Impacts of Climate Extremes to Interstate and Local Trucking Industry across NM and AZ:** This project addressed issues across southwest New Mexico, far west Texas, northwestern Chihuahua, and along I-10 in Arizona. Counties impacted in New Mexico include Hidalgo, Grant, Luna, Dona Ana, Otero, Catron, Sierra, and Socorro. Metropolitan areas include Las Cruces, El Paso, Ciudad Juarez, and Deming. People benefitted included those travelling on I-10 through the hazardous area of Lordsburg playa, and other wind erosion prone areas in southwestern NM. The project also addressed dust storms in rural ranchlands in Hidalgo and Luna Counties and residents of small towns in Columbus, Animas, and Lordsburg, NM. Dust storms frequently impact people travelling to and from Mexico especially on State Highway 11 in Luna County.
- **Adaptation to Climate Variability and Change: Markets, Policy, Technology, and Information:** Rural communities in Arizona have a variety of economic opportunities, but also face future environmental risks (e.g., drought, climate change, flooding). This project assesses various community-specific risks and evaluates investments in risk reduction in Pinal County, Santa Cruz County, and Tohono O'odham communities.
- **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, Graham, and Greenlee Counties in AZ, and tribal communities in northern AZ, where forage production is affected by drought. Crop insurance and disaster payments provide large injections of federal funds to agricultural communities dealing with drought. Small communities around Lakes Powell and Mead that face reduced recreation visitor spending as reservoir levels fall. Farmworkers face reduced work in response to drought-induced land fallowing.



Photo credit Dan Ferguson

- **An Assessment of Drought and Climate Vulnerability and Resilience in the Rio Grande Basin in New Mexico:** This research aims to inform equity in drought monitoring and to identify underserved communities impacted by drought in New Mexico, such as tribes, pueblos, and small-scale or subsistence farmers in rural New Mexico.
- **Visualization & Analysis Tools for the North American Monsoon – Integrating Citizen Science Data and Observations:** This work covers cities and counties Arizona, including Tucson, Phoenix, Mojave County, Pinal County, and Maricopa County, with plans to expand into more rural areas in the future.
- **Collaborative Research on Environmental Risks and Built Environment in the Borderlands of the Southwest:** This work focuses on Ambos Nogales on both sides of the U.S.-Mexico border, including Nogales, AZ and Nogales, Sonora, Mexico. Specifically, beneficiaries include students and faculty from high schools, universities, and technical colleges, and community collaborators in the borderland region.
- **Rethinking Social Vulnerability: Climate Risks and Impacts:** This work focuses on low-income households in South Tucson, AZ, which are predominantly Latinx. Researchers aim to assess climate impacts and thermal comfort through the lens of access and equity. The heat tool will expand to Maricopa County and urban Phoenix, based on a request from National Weather Service, Phoenix.
- **Community Climate Profiles:** Profiles will be or are completed for the communities of Prescott, Yavapai County, Flagstaff, Oro Valley, The Highlands at Dove Mountain, Gila River Indian Community, 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.
- **Adult Education Program:** D. Ferguson gave two in-person presentations for GED classes at the Yaqui Adult Education Center, titled: “Where are we headed and what can we do? A few thoughts on the evolving climate of the Southwest”
- In his role as the **New Mexico State Climatologist**, D. DuBois works with members of tribal organizations. He collaborated with the Southwest Climate Hub and the Native American Producer Success Project (NAPS) to recruit for CoCoRaHS and convene drought workshops. Participants were from San Juan, McKinley, and Bernalillo Counties in NM and Apache, Navajo, and Coconino Counties in AZ. As part of the Drought Learning Network, DuBois collaborated with the Santa Ana Pueblo and the Southwest Indian Polytechnic Institute to address drought across tribes in the Southwest. Participants were from Sandoval, Bernalillo, Valencia, Cibola Counties in NM.

COVID-19 Impacts on CLIMAS research

The COVID-19 pandemic continued to impact the pace of progress on some CLIMAS projects. The impact was less severe than the previous year, however, constraints on in-person meetings, travel, and fieldwork were commonly reported. Other constraints existed for project partners as their agencies and businesses shifted priorities to address the pandemic. Partners and research participants in rural areas sometimes did not have dependable access to internet, which slowed communication efforts. However, investigators made appropriate adjustments and progress was made on all CLIMAS projects.

Next Steps for 2022 – 2023

As we near the end of the current CLIMAS phase, we will wrap up a few existing projects that will continue for one more year through a no-cost extension and leveraged funds. In fall 2022, the CLIMAS team plans to implement a new five-year agenda. First, we will implement a program-wide strategy of structured engagement processes across the region to identify new partners, document climate equity issues, and develop a refined set of research questions. Second, we will carry out integrated inter- and transdisciplinary research projects focused on the three most pressing climate adaptation issues in our region: water availability, increasing aridity, and extreme heat events. Because human health and wellbeing are inextricably woven through climate research in these three areas, we will leverage the engagements, partnerships, and research being done within each project to formally assess how a health lens might further support ongoing projects which do not explicitly consider health impacts at present. Finally, through formal trainings, informal “learning-by-doing” approaches, ongoing outreach activities, and development of climate services to share climate information more effectively throughout the region, we will increase the capacity of Southwest researchers and practitioners—at all career stages but with a focus on the next generation—to work collaboratively on community-focused, problem-oriented, equity-centered climate research.

Program Evaluation

CLIMAS Investigators: G. Owen and M. deBlois

The CLIMAS program evaluation model uses data collected from annual reports and from periodic interviews with CLIMAS investigators (Fall 2019 and Winter 2022) and project partners (Spring 2022). In interviews with investigators and partners, we asked about the societal problem addressed in the project, methods for engagement with partners and the nature of the collaboration, and evidence of impact from the project and/or use of findings. An interim report will be available in Fall 2022. Several current projects will extend through Summer 2023, so the final CLIMAS impact report for 2017-2023 will be completed by Fall 2023.

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 five 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
- Socio-environmental impacts – changes to social and/or ecological 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 guide-book 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 next proposal, research projects, and approaches to engagement.

Evidence and Case Studies of Societal Impact

Impacts of Climate Extremes to Interstate and Local Trucking Industry across NM and AZ

This project increased the awareness of dust storms impacting highways through data measurements, and outreach to NMDOT, Department of Public Safety, emergency managers, trucking associations, and individual truck drivers. Researchers provided quantitative and qualitative evidence that dust events were lower after soil treatments were done at the Lordsburg playa. Evidence was collected through a combination of dust sensors and meteorological data collected at the playa treatment locations. Increased awareness combined with a reduction of dust storms and dust events on the playa reduced the impacts of highway hazards due to low visibility from dust. This project offers one solution for highway departments to adapt to extreme weather conditions. The reduction of dust storm related accidents translates into lives saved and dollars saved.

Based on ADOT statistics from 2019 annual average daily traffic on I-10 in Hidalgo County, NM can be up to 50,000 vehicles. Between 31 and 50 percent of the traffic on I-10 are trucks. A spring-time dust storm that lasts 12-hours can delay 15,000-25,000 trucks in one day. Many of these trucks are carrying goods that are paid on time of delivery.

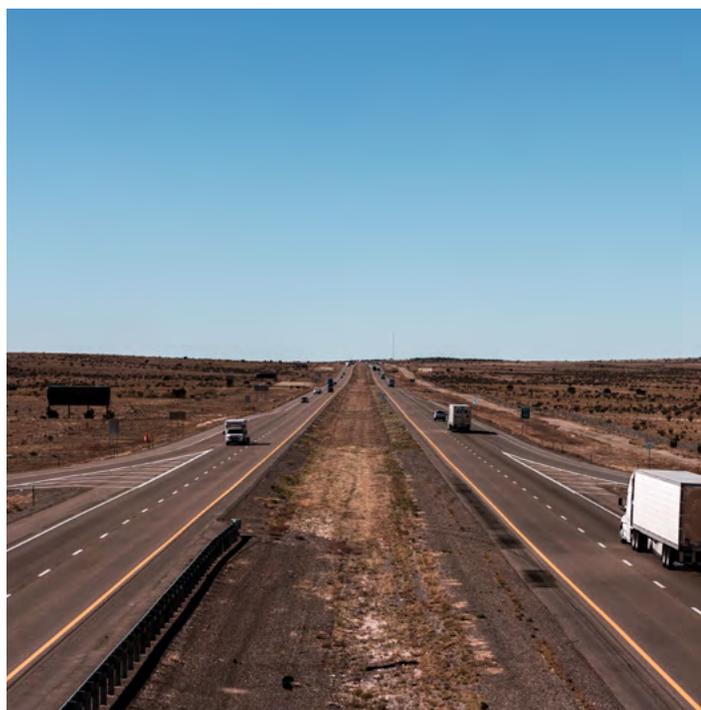


Photo credit Jahongir ismoilov Unsplash

Adaptation to Climate Variability and Change: Markets, Policy, Technology, and Information

Since the shortage on the Colorado River was declared, Pinal County in Arizona, where river allocations were taken away, is trying to switch back to groundwater sources. In doing so, people have found that groundwater infrastructure has deteriorated. Agricultural businesses in the county have solicited the USDA Natural Resource Conservation Service to deepen or refurbish wells. There is ongoing debate about which actions to take because groundwater use in Pinal County may not be the most sustainable choice.

CLIMAS researchers produced reports and papers about the contributions of agriculture to the Pinal County economy and modelled the local economic impacts of water reallocation from agriculture. Their findings show that reallocation impacts farmworkers and their livelihoods more than farm owners and managers. They also show how water reallocation might affect other sectors like natural resource conservation, national and state parks, and tourism industries. Information was provided in a series of reports and was presented to state and federal policymakers. The Arizona Department of Water Resources is turning these reports into learning modules to share with their broader network of stakeholders and partners, which includes the public, news media, and the state governor's office.

An economic analysis and environmental assessment of the Greene Wash Watershed in Pinal County is being used by Atkins (an NGO), Pinal County, and the USDA Natural Resources Conservation Service to inform their planning and are currently awaiting final decision from USDA-NRCS. Federal law requires that benefit-cost analysis be conducted for all federally funded flood control projects.

Photo credit Story by Lindsay Unsplash



Information Valuation Concerning Decisions Made in Response to Wildland Fires in the Southwest United States

CLIMAS researchers have convened a series of focus groups with wildland fire managers in the Southwest. These helped improve connectivity and interagency trust within the fire management community by bringing people together to collaborate across federal agency siloes. Participants said these focus groups helped them learn from one another about problems, ideas, and solutions.

This project has also increased awareness about the role of humidity in fire management. 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. CLIMAS and SWGACC partners collaboratively developed an experimental information product that shows the number of hours per day when the relative humidity is above or below 20%. This daily information tool is currently being used by firefighters and forecasters to stay aware of how humidity changes throughout the day and to inform timing of management strategies.

Sectoral Impacts of Drought and Climate Change

At the statewide Agribusiness & Water Council of Arizona's annual meeting and water conference, research from this project about the economic impacts of Colorado River Shortage declarations on state agriculture were the most cited body of research among speakers.

Stakeholders have used findings from this research to request and successfully receive \$10 million in water infrastructure funding from USDA.

Through this project, CLIMAS researchers developed good working relationships with staff at the Arizona Department of Water Resources and at Arizona Parks and Trails. Both organizations are supportive financially and in promoting research findings to other stakeholders statewide.



Photo credit Frankie Lopez Unsplash

Urban Heat and Health Interventions and Evidence Gaps

Findings from research about urban heat has informed the redevelopment of a green infrastructure map for Pima County in southern Arizona. This is the second version of this map, which has been expanded to include layers noting social and ecological resilience, such as tree coverage, bike paths, and food security. CLIMAS work informed a layer about heat impacts and a layer that depicts sources of heat relief like public cooling centers, splash pads, and pools. CLIMAS researchers responded to rapid needs during COVID. They tested heat levels and heat exposure at outdoor COVID testing and vaccination sites and provided short reports to county health departments so that they could implement preventative measures and keep health workers and the public safe.

This collection of work has spurred new connections across the state to help heat and health related agencies and the CDC to think about new ways to provide relief from extreme heat, looking beyond the models of cooling centers and increased shade.



Photo credit Allec Gomes Unsplash

Visualization & Analysis Tools for the North American Monsoon – Integrating Citizen Science Data and Observations

CLIMAS researchers developed a daily monsoon visualizer based on input from NWS Tucson and other local stakeholders. NWS Tucson wanted to revise their monsoon tracker with input and maps from CLIMAS, resulting from monthly meetings between NWS personnel and CLIMAS through June 2022. This year, the tracker expanded in geographical scope to include more rural areas, starting with Mojave County. This expansion was based on requests to build out the dataset and provide API assistance to curate data from the Arizona Department of Water Resources that would not be available otherwise. The National Weather Service, Tucson Office is using the daily monsoon visualizer to communicate about current monsoon precipitation on their [Monsoon Tracker](#) webpage.

Building Regional Food System Resilience in Southern Arizona – Learning from COVID-19

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 and farmer interviews. This collaboration was in support of the Arizona Food Systems Network’s development of a statewide food system plan. Because of this collaboration, PCFA then asked researchers to collaborate on a grant from to the Community Food Bank of Southern Arizona to help revitalize the food policy council’s membership and capacity. Participation and activity had dwindled during the pandemic, and they wanted to make sure PCFA was responsive to diverse local needs. The grant was awarded and an official partnership between PCFA, CLIMAS, and the Food Systems Research Lab has been established through summer 2023. CLIMAS and Lab researchers will provide data, facilitation, and evaluation assistance in support of PCFA’s efforts.

Photo credit Eduardo Jaeger Unsplash



Photo credit Leslie Cross Unsplash

The Influence of Climate on Lower Colorado Streamflow Variability: Present, Past, and Future

The publication of a peer-reviewed paper on climate and streamflow relationships in the upper Gila, Salt, and Verde Rivers was requested at the onset of the project by our management advisory group. A water and electric utility in central Arizona in particular, wanted to cite published science that described the influence of temperature on these rivers for their planning and operations. This work also influenced the way the utility communicates to their network of people, which includes Bureau of Reclamation, their customers, and the news media.

One research finding suggests that the influence of temperature on the Colorado River is much greater than its influence on the rivers in the lower basin. This has given the utility and other water managers confidence to explore reasons for why that is. The differences between the Colorado River and other river systems are important. There is concern that warming will take a huge bite out of Colorado River budget, which means there may be increased dependency on the Salt, Gila, and Verde rivers, with implications for regional water sustainability and resiliency.

Education and Training



Photo credit Melissa Merrick

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 Investigators G. Owen and B. McMahan, provides training and funding for graduate students to practice use-inspired research and science communication. Since its inception, the Fellowship program has funded 27 graduate students.

2021 Environment and Society Fellows:

The 2021 Fellowship cohort had a productive year, despite continuing pandemic restrictions. Listen to them reflect on their projects and findings in this special [CLIMAS podcast episode](#).

Lea Schram von Haupt

completed her Master's in the School of Natural Resources and the Environment and is now an employee of the U.S. Forest Service. Her research focused on fire restoration practices on the Coronado National Forest. She conducted and analyzed a survey about US Forest Service staff and stakeholder attitudes towards fire restoration and forest resilience influence forest planning. Findings were provided to Coronado National Forest partners via a research report and presentation. [Lessons Learned as a CLIMAS Environment & Society Fellow](#)

Moriah Bailey Stephenson

collaborated with Local Environmental Action Demanded (LEAD), an environmental justice organization in Ottawa County, OK. While navigating several personal issues throughout the year, she continued to collaboratively create a resource for residents who are at heightened risk for flooding due to the passage of the 2020 National Defense Authorization Act. [Reflections on 2021 as a CLIMAS Environment & Society Fellow](#)

Simone A. Williams,

a PhD candidate in the Arid Lands Resource Sciences program, is working with the Coconino Plateau Watershed Advisory Council and Coconino Plateau Watershed Partnership to characterize karst groundwater security issues, including quantity, quality, and access. She connected with several stakeholders in the region, which informed her research questions and design. Simone is now comparing the karst system to alluvial systems in Arizona. She continues to develop a searchable geodatabase and a story map of findings for both aquifer systems. [Reflections: Exploring Karst Groundwater Vulnerability and Risks in Arizona in 2021](#)

2022 Environment and Society Fellows

Julia Davies, a PhD candidate in the School of Geography, Development, and the Environment, is investigating how low-income urban households in Zambia maintain food security amid persistent social and environmental challenges. She aims to establish a more integrated understanding of the interactions among key components of urban food systems in sub-Saharan Africa, including household-scale urban agriculture, transitions in urban food retail environments, and urban food systems governance. As a CLIMAS Environment and Society Fellow, Julia will leverage her dissertation research to develop two online webinars, two policy briefs, and one op-ed with her partners at the Zambia Agriculture Research Institute.

Our cities are what we eat

Jake Dean is a Master's student in the Center for Latin American Studies. He is developing connections in an ejido in El Vizcaíno Biosphere Reserve to understand the socioecological and economic impacts of conservation development. Jake's research will focus on the tensions between whale conservation and the fishing industry of ELA, the social ecology and conservation advocacy of the surrounding area, and the rise of the whale-watching ecotourism industry in BCS.

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, and was awarded an Environment & Society Dissertation Improvement Grant. 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. The curriculum will be shared with other educators and through outreach programs in New Mexico to engage children in the local ecosystems where they live.

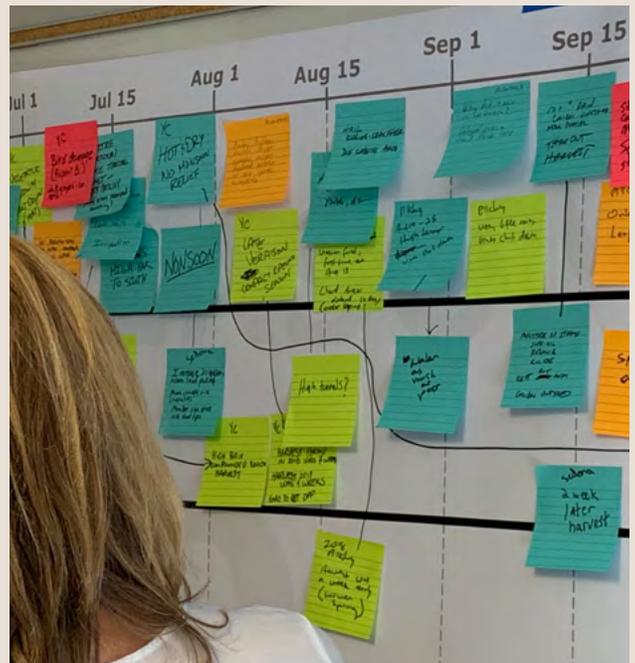


Photo credit by Jeremy Weiss

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 the TESS Program. This three-part online professional development series equips future generations of researchers, practitioners, political leaders, and educators to actively confront society's most complex environmental challenges. Courses were offered throughout 2021 and 2022. These courses are now being combined and re-designed for a 1-unit graduate course for the Global Change minor at UArizona.

Project Website:

[TESS: Transdisciplinary Environmental Science for Society](#)

Appendix A: Publications 2021 – 2022

- Austhof, E. and H.E. Brown, 2021. Flexibility and partnerships perceived as supportive of dual hazard response: COVID-19 and Heat Related Illness, Summer 2020. *Journal of Climate Change and Health* 4:100068. [doi:10.1016/j.joclim.2021.100068](https://doi.org/10.1016/j.joclim.2021.100068)
- Bellante, L., M.A. 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):1-3. doi:10.5304/jafscd.2022.113.017
- Bickel, A.K., D. Duval, and G. Frisvold. 2021. National Economic Development Analysis Greene Wash Watershed, Arizona. Report for Atkins, member of the SNC-Lavalin Group. In support of the Greene Wash Watershed Plan/ Environmental Assessment for the USDA Natural Resources Conservation Service. August 2021.
- Bickel, A.K., D. Duval, G. Frisvold. 2021. Drought and Agriculture in Arizona. Final Report to the Arizona Department of Water Resources. University of Arizona Cooperative Extension. December 2021.
- Bradford, J.B., Shriver, R.K., Robles, M.D., McCauley, L.A., Woolley, T.J., Andrews, C.A., Crimmins, M., Bell, D.M., 2021. Tree mortality response to drought-density interactions suggests opportunities to enhance drought resistance. *Journal of Applied Ecology*. <https://doi.org/10.1111/1365-2664.14073>
- Brown, H.E., L. Keith, V. Madera-Garcia, A. Taylor, N. Ramirez, and I. Ogata. 2022. Greening up for mosquitoes: A comparison of green stormwater infrastructure in a semi-arid region. *Journal of the American Mosquito Control Association* 38(2):109-112. Addresses need to understand potential downsides of poorly designed or maintained green infrastructure. <https://doi.org/10.2987/21-7055>
- Crimmins, M.A. 2021. NOAA releases 1991-2020 Climate Normals Update. *Arizona Rangelands - Quarterly Newsletter*, 1.
- Crimmins, M.A. 2021. **Climate change made Arizona's heat wave worse. And it won't be the last one.** The Washington Post. June 21, 2001.
- Crimmins, M.A., and T.M. Crimmins. 2021. The Ebb and Flow of Desert Rains and Blooms. *Vermillion Flycatcher*, 66(1), 6–9.
- Dew, T.J. 2021. It is a Dry Heat: Econometric Model of Historic Fires. M.S. Thesis, Department of Agricultural & Resource Economics, University of Arizona. <https://repository.arizona.edu/handle/10150/663407>
- Dinan, M., P.B. Adler, J. Bradford, M. Brunson, E. Elias, A. Felton, C. Greene, J. James, K. Suding, and E. Thacker. 2021. Making research relevant: Sharing climate change research with rangeland advisors to transform results into drought resilience. *Rangelands* 43(5):1850193. <https://doi.org/10.1016/j.rala.2021.08.004>
- Dinan M., E. Elias, N.P. Webb, G. Zwicke, T.S. Dye, S. Aney, M. Brady, J.R. Brown, R.R. Dobos, D. DuBois, B.L. Edwards. 2021. Addressing air quality, agriculture, and climate change across the Southwest and Southern Plains: A roadmap for research, extension, and policy. *Bulletin of the American Meteorological Society* 102(7):E1394-401. <https://doi.org/10.1175/BAMS-D-21-0088.1>
- Dormody T.J., P. Skelton, G. Rodriguez, D.W. Dubois, and D. VanLeeuwen. 2021. Assessing the Impact of a Weather and Climate Curriculum on Youth Science Comprehension, *Journal of Agricultural Education* 62(3):153-166. <https://doi.org/10.5032/jae.2021.03153>
- DuBois, D. 2022. Dust Mitigation Monitoring Project, Final Report. Prepared for NMDOT Research Bureau. Prepared by New Mexico State University, Department of Plant and Environmental Sciences.
- Duval, D., A.K. Bickel, and G. Frisvold. 2021. Effects of Reservoir Levels on Arizona National Recreation Area Visitation, Visitor Spending, and Local Economies. *Journal of the American Water Resources Association*. JAWR-21-0052-P. <https://doi.org/10.1111/1752-1688.12962>
- Duval, D., A.K. Bickel, and G. Frisvold. 2021. The Costs of Wildfire in Arizona: A Survey of Methods, Data, and Estimates. Final Report to the Arizona Department of Water Resources. University of Arizona Cooperative Extension. December 2021.
- Duval, D., A.K. Bickel, G. Frisvold, W. Zheng. 2021. **The Nature-Based Restorative Economy (NBRE) in Santa Cruz County, Arizona.** Department of Agricultural and Resource Economics, University of Arizona, Cooperative Extension. Tucson, AZ.

- Ferguson, D.B., A.M. Meadow, and H.P. Huntington. 2022. Making a Difference: Planning for Engaged Participation in Environmental Research. *Environmental Management* 69:227–243. <https://doi.org/10.1007/s00267-021-01585-5>
- Ford, M. 2022. *Connections Between Cropping Trends, Water Availability, and Groundwater Regulations*. M.S. Thesis. University of Arizona Hydrology & Atmospheric Sciences.
- Gerlak, A., S. Karambelkar, and D.B. Ferguson. 2021. Knowledge Governance and Learning: Examining Challenges and Opportunities in the Colorado River Basin. *Environmental Science & Policy* 125:219-230. <https://doi.org/10.1016/j.envsci.2021.08.026>
- Gerlak, A., H. Vafai, D.B. Ferguson, and L. Salame. 2021. Science Diplomacy in Education. In *Sustainable Development for the Americas: Science, Health, and Engineering Policy and Diplomacy*, eds. E.W. Colglazier, H.A. Vafai, K.E. Lansey and M.D. Bryson: CRC Press.
- Hansen, H. 2022. *Climate, Prices, and Federal Programs: Choices for Irrigated Agriculture*. M.S. Thesis, University of Arizona Agricultural and Resource Economics.
- Johnson, N., K.S. Erickson, D.B. Ferguson, M.B. Jäger, L.L. Jennings, A.R. Juan, S. Larson, W.K.S. Smythe, C. Strawhacker, A. Walker, and S.R. Carroll. 2021. The Impact of COVID-19 on Food Sovereignty for Alaska Natives. In *2021 Arctic Report Card*, eds. T.A. Moon, M.L. Druckenmiller and R.L. Thoman. NOAA.
- Keith, L. and A.K. Gerlak. 2021. **There's no place in the US safe from the heat.** August 20, 2021.
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- Kinkaid, E., G. Owen, and L. Bellante. 2021. **Tucson Opinion: COVID-19 impacts demonstrate why Southern Arizona needs more farmers.** *Arizona Daily Star*, July 17, 2021.
- Meerow, S. and L. Keith. 2021. Planning for extreme heat: A national survey of U.S. planners. *Journal of the American Planning Association*. <https://doi.org/10.1080/01944363.2021.1977682>
- Meko, D.M, C.A. Woodhouse and A.G. Winitzky. 2022. Tree-Ring Perspectives on the Colorado River: Looking Back and Moving Forward. *Journal of the American Water Resources Association*, 1-18. <https://doi.org/10.1111/1752-1688.12989>
- Mokari E., D. DuBois, Z. Samani, H. Mohebzadeh, K. Djaman. 2021. Estimation of daily reference evapotranspiration with limited climatic data using machine learning approaches across different climate zones in New Mexico. *Theoretical and Applied Climatology*, <https://doi.org/10.1007/s00704-021-03855-y>
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- Pereira, M. 2022. *Statistical Relationships Between Groundwater, Climatic, and Economic Factors in Southeastern Arizona*. M.S. Thesis. UArizona Hydrology & Atmospheric Sciences.
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Appendix B: Current CLIMAS Projects Index

(Organized alphabetically by project lead PI's last name)

Identifying Gaps in Stakeholder Needs Regarding the Climate and Health Connection

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

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

End Users: AZ county health departments; Arizona Department of Health Services, and other community groups across the state at the climate/health interface. Provide support for Pinal and Maricopa County's Implementation and Monitoring Strategies (IMS).

Populations Benefited: Pima County; Populations at risk to heat in Pima County, including homeless populations

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 supporting the monitoring and evaluation of the efforts developed under BRACE through the Climate and Health Adaptation Monitoring Program (CHAMP). 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 inform adaptation and mitigation plans for Arizona and help build partnerships throughout the state with CLIMAS and other groups.

Findings: In January 2021, we conducted key informant interviews among BRACE recipients to understand how health departments responded to the dual hazards of Heat Related Illness (HRI) and COVID-19. Health jurisdictions who worked in both heat preparedness and on the COVID-19 response highlighted three themes to maintain the public health capacity throughout the pandemic: 1) adapting to changing roles and responsibilities; 2) building and strengthening inter-organizational partnerships; and 3) maintaining flexibility through

cross-disciplinary training. With impending impacts of a changing climate and extreme events with subsequent public health impacts, responses that meet dual purposes are necessary.

Outputs

Data: Maps of Cooling Centers in Tucson. Used by Pima Association of Governments, Tucson Pima Collaboration to End Homelessness, Chicanos Por La Causa.

<https://arcg.is/01zfLq0>

Publications: Austhof, E. and H.E. Brown, 2021. Flexibility and partnerships perceived as supportive of dual hazard response: COVID-19 and Heat Related Illness, Summer 2020. *Journal of Climate Change and Health* 4:100068. [doi:10.1016/j.joclim.2021.100068](https://doi.org/10.1016/j.joclim.2021.100068)

Workshops: Tucson Heat Management Meeting. With representatives from National Weather Service, Tucson; Pima County Office of Emergency Management; Tucson Water; City of Tucson; Pima County Health Department; Pima Association of Governments. 12/15/2021. 6th Annual Arizona Extreme Heat Planning Workshop. Hosted by UArizona, Arizona State University, & Arizona Department of Health Services; NOAA. 220 attendees. April 2022.

Presentations: Climate Change and Health Lecture. College of Medicine, UArizona. March 2022
Health and economic benefits are motivations for individual climate action. Annual Public Health Poster Forum. College of Nursing, UArizona. April 2022
Responding to the health effects of climate change. Psychological Science and the Climate Crisis: Thinking globally, Acting locally. Psychology Department, UArizona. May 2022
Health Implications of Urban Heat in the Arid Southwest. 6th Annual Arizona Extreme Heat Planning Workshop. In City of Tucson and Tucson Water's 12th Urban Heat Island Workshop: Urban Heat Island and Equity. April 2022

Media citations: Mann, D. As Temperatures Rise, Workers in Southwest Face Health Issues. *HealthDay* 5/18/2022. Re-published in seven additional news sources.

New Funding Acquired: AIR Resilience Program, Climate-Health Resilience through Physician Education. With UArizona College of Medicine, Tucson and Phoenix campuses; Maricopa County Health Department \$70,406. Fall 2021. One part of this work is a "Climate

Champions in Health” program focused on recognizing health practitioners who engage with climate.

Is Adaptation Maladaptation? An assessment of mosquitoes and water harvesting

CLIMAS Investigators: H. Brown, L. Keith

Research Partners: Tucson Water;

Pima County Vector Control

End Users: Tucson Water; Pima County Vector Control

Abstract: Rainwater harvesting design techniques such as green infrastructure are heralded as tools for building a sustainable community and resilience against climate change impacts. When rainwater harvesting strategies fall into disrepair or are designed improperly, they may inadvertently become sources of mosquitoes. Well-maintained green infrastructure design strategies have the greatest impact on conservation while limiting the negative consequences of mosquitoes. If green infrastructure is to be used as an adaptation technique then it is important to better understand when it works best.

Findings: In this study, undergraduate researchers visited green stormwater infrastructure sites after a rain event to check for water and mosquitoes. One large basin near a parking garage was positive for mosquito larval and failed to drain even after 9 days.

Outputs

Publications: Brown, H.E., L. Keith, V. Madera-Garcia, A. Taylor, N. Ramirez, and I. Ogata. 2022. Greening up for mosquitoes: A comparison of green stormwater infrastructure in a semi-arid region. *Journal of the American Mosquito Control Association* 38(2):109-112. Addresses need to understand potential downsides of poorly designed or maintained green infrastructure.

<https://doi.org/10.2987/21-7055>

Community-Based Responses to Climate Water Challenges

CLIMAS Investigators: B. Colby, H. Hansen

Additional Investigators: A. Lien, UArizona - School of Natural Resources and Environment; A. Hullinger, UArizona - Water Resources Research Center; Graduate Assistants: B. McGreal, M. Pereira, M. Ford, D. Tadych

Research Partners: Flood & Flow Committee (Patagonia); Queen Creek Working Group (Superior); Planning and Zoning Commission (Benson); City of Benson; Town of

Patagonia; Town of Superior; U.S. Bureau of Reclamation; U.S. Dept. of Agriculture; Arizona Department of Water Resources; Central Arizona Project; Salt River Project; University of Nevada Reno; University of Colorado; Sonoran Institute; The Nature Conservancy; Santa Cruz Watershed Collaborative

End Users: Public agencies: U.S. Bureau of Reclamation, U.S. Dept. of Agriculture, Arizona Department of Water Resources, Central Arizona Project, Salt River Project; Employees and elected officials of town and cities: planners, managers, mayors, councils; County commissioners

Additional Support: DOI Climate Adaptation Science Centers; DOI Landscape Conservation Cooperatives

Populations Benefited: Town of Superior, AZ (85173); Town of Patagonia, AZ (85624); City of Benson, AZ (85602, 85630). Rural planners, administrators and elected officials often lack funding, staff and expertise with relevant data needed to conduct or apply climate/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.

Abstract: This project examines community perceptions and decisions about climate science, economics, and policies associated with resilience strategies that address increasing water scarcity in the Southwest. Strategies to be evaluated include: investments in built infrastructure like reservoirs and pipelines; incentive-based risk-sharing agreements; and watershed ecosystem services. The project emphasizes the role that ecosystem services can play in buffering water impacts of climate change, as well as the potential for climate mitigation as a strategy to enhance water supply security.

This year, investigators engaged three rural communities as project partners: the Town of Patagonia, Town of Superior, and City of Benson. They agreed to provide guidance through advisory meetings, review of project milestones, and participation in workshops. This project will develop Community Drought Preparedness and Response Plans for these three communities, applying new and emerging data in support of local and regional decision-making. Plans will consider local conditions, community priorities, climate data and climate projections, and economic costs/benefits and policy trade-offs in the evaluation of potential drought response options. Final plans will incorporate scaled data and research for water planning priorities, in accordance with A.R.S. §45-342, to be applied by the community.

Outputs

Publications: Colby, B. and H. Hansen. IN PRESS. Incentive-Based Policies for Urban Water Conservation and Supply Reliability in Colorado River Basin. *Journal of the American Water Resources Association*. This article provides review of the array of urban water conservation programs and watershed protection programs being implemented, and of ways to evaluate such programs. Useful to urban water managers, planners, regulatory agencies, and community leaders.

Hansen, H. 2022. *Climate, Prices, and Federal Programs: Choices for Irrigated Agriculture*. M.S. Thesis, UArizona Agricultural and Resource Economics. This study examines agricultural water use and crop mix selection in major irrigation districts of central Arizona. It suggests ways to manage the impacts of impending changes in central Arizona's water supplies.

Ford, M. 2022. *Connections Between Cropping Trends, Water Availability, and Groundwater Regulations*. M.S. Thesis. UArizona Hydrology & Atmospheric Sciences. This study explores how the type of water source (groundwater, or local or imported surface water) or groundwater regulations have influenced historical cropping patterns across Arizona. By comparing unregulated and regulated groundwater areas, the study finds that irrigated acres are increasing in unregulated regions while decreasing in regulated regions. Groundwater dominated parts of the state are experiencing increases in acreage of high water use crops, while surface water dominated regions have growing acres of low water use crops.

Pereira, M. 2022. *Statistical Relationships Between Groundwater, Climatic, and Economic Factors in Southeastern Arizona*. M.S. Thesis. UArizona Hydrology & Atmospheric Sciences. This study explores statistical relationships between groundwater levels and economic and climatic variables in two rural basins in southeastern Arizona. A depth-to-water metric is significantly related to non-exempt wells, housing units, per capita income, and planted acreage. Well installation is strongly related to developed acreage, suggesting that development patterns, not crop irrigation, are most strongly linked to groundwater declines.

Presentations: Drought Response Planning for Water Resilient Communities. Town of Superior Queen Creek Working Group. September 2021. Affirmative response from host and decisions to participate in project. Drought Response Planning for Water Resilient Communities. Town of Patagonia Flood & Flow Committee. May 2022. Affirmative response from host and decision to participate in project. Multiple expressions of appreciation and interest from audience members.

Advisory Roles: Colby: Board of Trustees, Arizona Nature Conservancy 2014 – 2022; U.S. Bureau of Reclamation, reviewer for external research grants funding program 2016 – 2022.

Hullinger: Santa Cruz Watershed Collaborative, member of Coordination Team and Restoring Flows and Floodplains Working Group, reviewer of Watershed Management Plan 2021 – 2022; Cobre Valley Watershed Partnership advisor and reviewer for Watershed Management Plan 2021 – 2022. Cobre Valley Science Coordination Team 2021 – 2022; Aravaipa Watershed Conservation Alliance advisor and reviewer for Watershed Management Plan 2021 – present. Town of Superior Queen Creek Working Group coordinator 2021 – present.

USDA Livestock Forage Disaster Program and Ranching in the Southwest U.S.

CLIMAS Investigators: M. Crimmins, M. McClaran, G. Frisvold, C. Greene

Research Partners: National Weather Service; USDA Natural Resources Conservation Service; USDA Southwest Climate Hub; 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

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 applica-

tion 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. This project aligns with other projects across the region to improve the efficiency and efficacy of drought monitoring across the Southwest, including:

- A CLIMAS project that evaluates drought indices through soil moisture modeling, resulting in a drought monitoring ‘playbook’ for land managers in AZ (led by M. Crimmins)
- A USDA Southwest Climate Hub project to engage rural communities and ranchers in volunteer precipitation monitoring to improve the characterization of drought conditions in rural areas and to help inform the USDM (led by C. Steele)
- Assessing the impact of drought on agricultural production, including ranching, in Arizona. We share supporting data including USDM and drought index data from our project to support their analysis (led by A. Kerna Bickel and G. Frisvold)
- A CLIMAS project to assess the impact of drought on the Rio Grande watershed in New Mexico (led by C. Greene)
- A recently funded USDA AFRI grant to assess the impacts of drought and climate change on ranchers and land managers across the western U.S. (led by K. Suding)

Evaluating Existing and Developing New Drought Indices Using Modeled Soil Moisture Time Series

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

Research Partners: The Nature Conservancy

End Users: Land managers from USDA-Natural Resource Conservation Service; U.S. 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: USDA Southwest Climate Hub, NASA Space Grant Fellowship

Abstract: To assess the performance of simple drought

indices like the SPI and PDSI relative to potential soil moisture regimes, we used 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 assess when and where traditional drought indices align with modeled soil moisture stress. The modeling approach also assesses the performance of temperature-based indices like the SPEI and further explores the role of increasing temperatures in driving drought stress.

The initial project study location was at Las Cienegas NCA, but we have broadened to 240 study sites in 4 Major Land Resource 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.

Outputs

Presentations: McKellar, T. The Relationship Between Multiscalar Meteorological Drought Indices and Soil Water Availability Across the Southwestern United States. ENVision Graduate Research Workshop. Dept. of Environmental Science, The University of Arizona. March 2022.

Impacts of Climate Extremes to Interstate and Local Trucking Industry across NM and AZ

CLIMAS Investigators: D. DuBois, S. Engle, M. DeAntonio, N. Franco, T. Bell, J. LeBlanc

Research Partners: G. Lundeen, National Weather Service, Santa Teresa; K. Waters, National Weather Service, Phoenix; G. Michaud, Bureau of Land Management Las Cruces; B. Edwards and N. Webb, Jornada Experimental Range and National Wind Erosion Network; D. Hadwiger, T. Botkin, B. Hutchinson, NM Department of Transportation; T. Gill, University of Texas El Paso; R. Garcia, Mesilla Valley Transportation

End Users: NOAA-NWS Albuquerque, Santa Teresa, Phoenix, and El Paso Weather Forecast Offices; New Mexico Department of Transportation; Arizona Department of Transportation; Mesilla Valley Trucking; NM Trucking Association; Bureau of Land Management, Las Cruces

Populations Benefited: This project addressed issues across southwest New Mexico, far west Texas, northwestern Chihuahua, and along I-10 in Arizona. Counties impacted in New Mexico include Hidalgo, Grant, Luna, Dona Ana, Otero, Catron, Sierra, and Socorro. Metropolitan areas include Las Cruces, El Paso, Ciudad Juarez, and Deming. Peoples benefitted included those travelling on I-10 through the hazardous area of Lordsburg playa, and other wind erosion prone areas in southwestern NM. Our project also addressed dust storms in rural ranchlands in Hidalgo and Luna Counties and residents of small towns in Columbus, Animas, and Lordsburg, NM. Dust storms also frequently impact people travelling to and from Mexican points especially on state highway 11 in Luna County.

Additional Support: NM Department of Transportation

Abstract: Transportation along our nation's highways forms a basis for our economy, moves our food from place to place, and serves to connect our communities. Extreme weather impacts our transportation system in many ways and for this project, particularly during drought, we focus on dust storms. Our project goal is the increase the resilience of drivers during these events. Our partners include the New Mexico Department of Transportation and trucking companies who are interested in improving the way they handle these dust storms through education and warning. Our project serves to assist them in characterizing and documenting the climatic and visual conditions that exist during these storms through interviews with drivers and road managers, in addition to time-lapse camera imagery and dash cams.

Findings: Visibility does not always improve with increased seat height of the observer. The difference between 1- and 3-meter empirical equations was due to having higher dust concentrations at 1-meter. More dust particles accumulate closer to the ground (1-meter) as gravitational deposition makes it more difficult to be suspended higher than the 3-meter height. Dispersion also plays a part in this phenomenon as well. In some cases, 3-meter concentrations were higher than the 1-meter levels. Although not explored in detail, this was thought to be caused by turbulent convective behavior of the dust that was driven by a very unstable vertical profile of air near the surface. Convective dust events can occur without much warning and cause as much or in some case more damage than spring synoptic storms that last a full day. The convective dust events are triggered by thunderstorms and can pop

up quickly depending on amount of atmospheric moisture, stability of the atmosphere, temperature, sunlight, and winds. Based on observations from GOES satellite, summertime convection often occurs over the Gila or Chiricahua Mountains and can spark growth of storms by upslope forced convection.

We successfully demonstrated the use of inexpensive time-lapse cameras to assess dust events. Observations included the very fast evaporation and movement of water by wind. Observations of the dust emissions show complexity and the importance of vertical motion and convection in the dispersion of dust plumes. One of the difficulties in using this method was the level of effort to extract the dust events from the images. We explored the use of machine learning to examine the images during a short pilot project and the method proved successful.

Outputs

Publications: DuBois, D. 2022. Dust Mitigation Monitoring Project, Final Report. Prepared for NMDOT Research Bureau. Prepared by New Mexico State University, Department of Plant and Environmental Sciences. This study examined the effectiveness of land use interventions on mitigating blowing dust and the frequency of dust-related traffic crashes at the Lordsburg Playa on Interstate 10 in southwest New Mexico. The report summarized an important project where we monitored dust storms impacting interstate 10 before and after dust control activities. Lessons learned from this study can be used in other regions with similar issues with dangerous dust storms.

Presentations: Dust Events on the Lordsburg Playa Based on Time-lapse Camera Imagery in 2020 and 2021. Southern NM & Western U.S. Dust Symposium, NMED, NASA. October 2021. There is an increased awareness of the impacts of dust on health and safety in southern NM over the past several years. NMED partnered with NASA to examine ways to improve dust forecasts and human health aspects such as Valley Fever. This talk led to more discussion from the NASA group and connections to others working to use time-lapse cameras for dust storm monitoring.

Summary of Dust Storms in the Spring 2022. Southern NM & Western U.S. Dust Symposium, NMED, NASA. May 2022. Based on the drought intensity, there has been an increased need for knowing more about wind erosion and health impacts this year. Follow-up discussions ensued about PM10 and PM2.5 filters to look at fungi and other biological components of airborne aerosols.

Social Media: Posted tweets related to this project throughout the year, mostly relating to dust storms or weather events on Lordsburg playa.

Advisory Role: DuBois is the U.S. Co-leader of the Air Quality Task Force for the U.S. EPA's Border 2025 Program. Task Force co-leaders oversee the creation of action plans and track and report on progress in implementing the plans; act as a spokesperson for the Task Force and be informed to answer questions from the public, stakeholders and/or media; and convene a Task Force meeting at least annually, among other activities.

Impacts: This project increased the awareness of dust storms impacting highways through our measurements, outreach to NMDOT, Department of Public Safety, Emergency Managers, trucking associations, and individual truck drivers. We provided quantitative and qualitative evidence that dust events were lower after soil treatments were done at the Lordsburg playa. This was done with a combination of dust sensors and meteorological data collected at the playa treatment locations. Increased awareness combined with a reduction of dust storms and dust events on the playa reduced the impacts of highway hazards due to low visibility from dust. This project offers one solution for highway departments to adapt to extreme weather conditions.

The reduction of dust storm related accidents translates into lives saved and dollars saved. Based on ADOT statistics from 2019 annual average daily traffic on I-10 in Hidalgo County, NM can be up to 50,000 vehicles. Between 31 and 50 percent of the traffic on I-10 are trucks. A spring-time dust storm that lasts 12-hours can delay 15,000-25,000 trucks in one day. Many of these trucks are carrying goods that are paid on time of delivery.

Adaptation to Climate Variability and Change: Markets, Policy, Technology, and Information

CLIMAS Investigators: G. Frisvold; W. Zheng

Research Partners: U.S. Department of Agriculture, Farm Services Agency (FSA); Natural Resources Conservation Service; U.S. Forest Service; Arizona Department of Agriculture; The Nature Conservancy; The Audubon Society; Borderlands Restoration Network; Sky Island Tourism Alliance; Atkins Global

End Users: Tohono O'odham Nation; The Nature Conservancy; The Audubon Society; Borderlands Restoration Network; Sky Island Tourism Alliance; Town of Patagonia;

Santa Cruz County Board of Supervisors; Pinal County Board of Supervisors

Populations Benefited: Pinal County, Santa Cruz County; Tohono O'odham communities facing flood risk. Rural communities in Arizona have a variety of economic opportunities, but also face future environmental risks (e.g., drought, climate change, flooding). This project assesses various community-specific risks and evaluates investments in risk reduction.

Additional Support: USDA Natural Resources Conservation Service (through a sub-contract with Atkins Global) and the Town of Patagonia, AZ

Findings: Santa Cruz County's Nature Base Restorative Economy (NBRE), which includes nature-based industries, such as agriculture, nature-based tourism, and environmental conservation and restoration activities, contributes more than \$121 million in county sales and 1,200 jobs. Opportunities to expand nature-based tourism can be furthered by investments to improve tourism infrastructure, such as lodging and other amenities. Opportunities exist to help protect and preserve working landscapes through successional planning for ranchers and support for future generations of farmers and ranchers in the county.

Flood control is a major consideration in the county, particularly in the Nogales area. Ongoing investment in infrastructure for flood control represents an opportunity to apply principles of conservation and restoration to such projects, enabling co-benefits such as habitat creation, revegetation, and groundwater recharge.

Outputs

Publications: Duval, D., A.K. Bickel, G. Frisvold, W. Zheng. 2021. The Nature-Based Restorative Economy (NBRE) in Santa Cruz County, Arizona. Department of Agricultural and Resource Economics, University of Arizona, Cooperative Extension. Tucson, AZ. Various stakeholder groups in Santa Cruz County were interested in the role of nature- and conservation-based activities in the local economy and to explore means of promoting those activities. We presented report results to the Santa Cruz County Board of Supervisors and stakeholders have posted the study to their social media sites.

<https://economics.arizona.edu/nature-based-restorative-economy-santa-cruz-county-arizona>

Bickel, A.K., D. Duval, and G. Frisvold. 2021. National Economic Development Analysis Greene Wash Watershed, Arizona. Report for Atkins, member of the SNC-Lavalin Group. In support of the Greene Wash Watershed

Plan/Environmental Assessment for the USDA Natural Resources Conservation Service. Federal law requires that benefit-cost analysis be conducted for all federally funded flood control projects. This was developed for the USDA, NRCS, and Pinal County. Awaiting final decision from NRCS.

Presentations: The Nature-Based Restorative Economy (NBRE) in Santa Cruz County, Nogales, AZ. Santa Cruz County Board of Supervisors Meeting. Supervisors wanted to ask questions about the NBRE study. We were invited to give a subsequent presentation to the county Chamber of Commerce.

Social Media: Patagonia Alliance (PARA) posted a link to the NBRE study on Instagram, Facebook, and Twitter. Borderlands Restoration Network posted link to NBRE study on Facebook. Arizona Trails posted link to NBRE study on LinkedIn.

Media citations: Gervasi, A. 2022. [How much does nature contribute to county's economy?](#) Nogales International, 4/21/22.

Nelson, M. 2022. [New Economic Impact Study Proves Benefits for Nature and Restoration Economy in Southern Arizona](#). Arizona Trail News, 3/18/22.

Williams, S. 2022. [University of Arizona Releases Study of Economic Benefits of Nature-Based Industries in Santa Cruz County](#). Save the Scenic Santa Ritas, 3/27/22.

Impacts: Local governments and NGOs are using our study results in their policy and planning debates. The USDA is using our results to make decisions regarding flood control projects. If the Greene Wash project in Pinal County is approved, flood damages would be reduced for about 200 structures for a 2-year flood event to more than 1,000 structures for a 500-year flood event. Flood damages would be reduced for 8,000 to 20,000 acres of cropland.

The estimated annual impact of improved flood control in Pinal County was estimated to be more than \$500,000 per year. Benefits were measured in terms of reduced flood damage to crops, buildings, and structures.

Information Valuation Concerning Decisions Made in Response to Wildland Fires in the Southwest United States

CLIMAS Investigators: G. Frisvold, D. Ferguson, M. Crimmins, W. Zheng, T. Dew

Research Partners: C. Maxwell, U.S. Forest Service; NOAA – National Weather Service; Bureau of Land Management; Arizona Department of Forestry and Fire Management; New Mexico Forestry Division; Bureau of Indian Affairs

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

Populations Benefited: Areas in the wildfire-urban interface in Arizona and New Mexico. Tribal communities in areas at risk from wildfire damage.

Additional Support: NOAA National Weather Service (NWS); NOAA Regional Climate Services Directors (RCSD)

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.

Findings: The Wildfire Decision Support System (WFDSS) is intended to assist “fire managers and analysts in making strategic and tactical decisions for fire incidents.” Previous qualitative research suggests that WFDSS is used more for documenting and justifying decisions after they are made than for making initial decisions. Our quantitative survey supports and reinforces this earlier finding. 58% of respondents said they agreed or strongly agreed that they use WFDSS primarily to document, rather than inform, decisions. In contrast 1/3 of respondents agreed or strongly agreed that they used WFDSS to inform their decisions prior to making them.

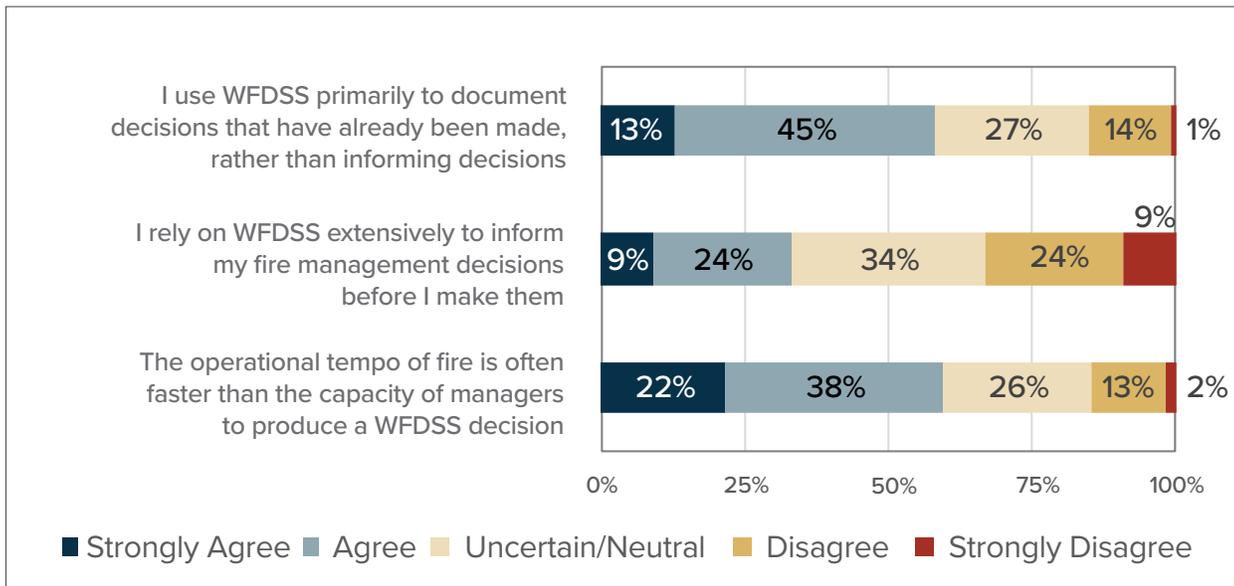


Figure 1. Use of WFDSS and decision-making

WFDSS received relatively higher marks among respondents as a means of organizing data and documenting decision. Of respondents, 87% found WFDSS somewhat or very helpful at documenting fire management decisions. More than 85% found WFDSS somewhat or very helpful for aggregating data, visualizing data, and understanding values at risk.

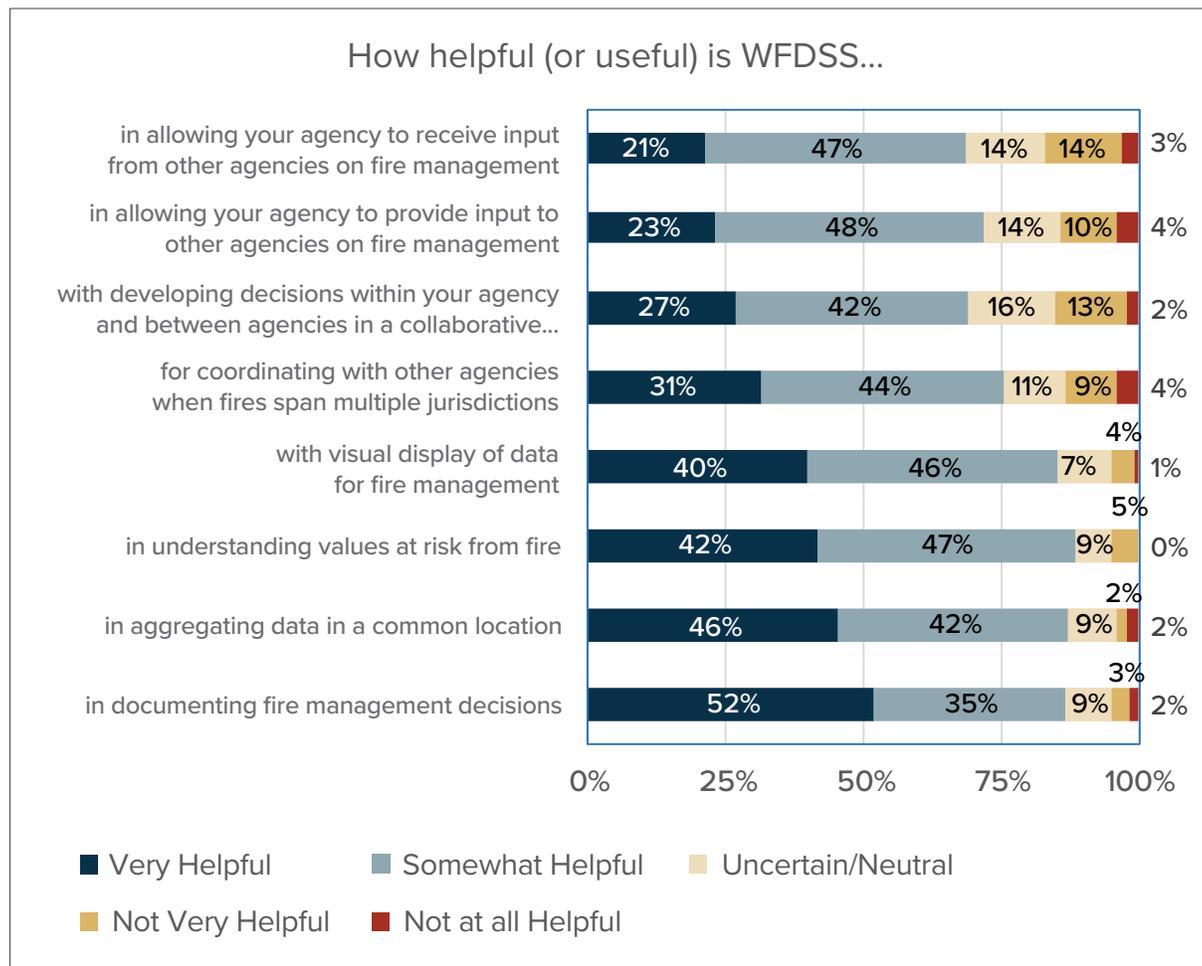


Figure 2. Helpfulness and Usefulness of WFDSS

Outputs

Publications: Dew, T.J. 2021. It is a Dry Heat: Econometric Model of Historic Fires. M.S. Thesis, Department of Agricultural & Resource Economics, UArizona. Although average relative humidity has not been much used in previous studies predicting fire size and suppression costs, for Arizona it was found to be a significant negative predictor of both suppression costs and of very large fires. Many studies estimate the determinants of fire size and suppression costs evaluating data ex post. This study attempts to improve prediction of large fires. <https://repository.arizona.edu/handle/10150/663407>

Impacts: CLIMAS researchers have convened a series of focus groups with wildland fire managers in the Southwest. These helped improve connectivity and interagency trust within the fire management community by bringing people together to collaborate across federal agency siloes. Participants said these focus groups helped them learn from one another about problems, ideas, and solutions.

This project has also increased awareness about the role of humidity in fire management. 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. CLIMAS and SWGACC partners collaboratively developed an experimental information product that shows the number of hours per day when the relative humidity is above or below 20%. This daily information tool is currently being used by firefighters and forecasters to stay aware of how humidity changes throughout the day and to inform timing of management strategies.

Sectoral Impacts of Drought and Climate Change

CLIMAS Investigators: G. Frisvold

Research Partners: A. Kerna Bickel and D. Duval, Agricultural and Resource Economics, UArizona; National Integrated Drought Information System (NIDIS); USDA Natural Resources Conservation Service; USDA Risk Management Agency; Graham and Greenlee Counties; Town of Patagonia Planning and Development Committee; Arizona Department of Water Resources; Arizona Parks and Trails; Gila River Indian Community; University of Arizona Federally Recognized Tribes Extension Program; Maricopa County Food Coalition; Arizona Farm Bureau; Cotton Incorporated; Arizona Agri-Business and Water Council

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

Populations Benefited: Agriculture-based communities, particularly in Pinal, Graham, and Greenlee Counties. Crop insurance and disaster payments provide large injections of federal funds to agricultural communities dealing with drought. Communities around Lakes Powell and Mead that may have reduced recreation visitor spending as reservoir levels fall. Farmworkers that may lose work in response to drought-induced land fallowing. Tribal communities, especially in the northern part of the state where forage production is affected by drought. Tribal communities facing flood risk in Pinal County.

Additional Support: NIDIS; Arizona Department of Water Resources; NOAA Regional Climate Centers; USDA Climate Hubs; U.S. Geological Survey; U.S. Bureau of Reclamation; National Park Service; Arizona State Parks Board

Findings: For cropland production in Arizona, which is virtually all irrigated, the effects of drought on crop production are quite different from those in the major agricultural production regions of the Plains and Midwest. In those areas, which are largely rainfed production, drought has significant negative effects on crop yields. In Arizona, drought has little effect on crop yields. Drought primarily affects acreage planted. If farmers have insufficient irrigation water supplies, they cut back acreage, but yields on remaining planted acres remain relatively stable. In Arizona, the main impacts of drought are from

longer-term, hydrologic drought causing acreage reductions, rather than short-term drought affecting yields. The effect of drought on outdoor recreation depends on the length of the drought measure. Short-term drought as measured by the one-month Standard Precipitation Index (SPI) is positively associated with visits, while longer-term drought as measured by the 24-month Standard Precipitation Index (SPI) is negatively associated with visits. People may avoid or delay outdoor recreation in especially rainy months (short-term effect). Longer term drought can reduce streamflows, water in seeps in springs, and wildlife viewing opportunities, while increasing wildfire related park closures.

Outputs

Publications: Duval, D., A.K. Bickel, and G. Frisvold.

2021. Effects of Reservoir Levels on Arizona National Recreation Area Visitation, Visitor Spending, and Local Economies. Journal of the American Water Resources Association. JAWR-21-0052-P. This study estimates the economic impacts of falling reservoir levels on visits to Lake Powell (Glen Canyon National Recreation Area [NRA]) and Lake Mead NRA, including reductions on recreation benefits and spending in local economies. It is the first study in over 25 years of economic impact of falling water elevations at Lake Powell and Lake Mead. Provides information to local county governments on economic impacts of drought. Different programs are being implemented to keep more water in Lake Powell and Lake Mead. This study quantifies some recreation benefits of these programs.

<https://doi.org/10.1111/1752-1688.12962>

Bickel, A.K., D. Duval, G. Frisvold. 2021. Drought and Agriculture in Arizona. Final Report to the Arizona Department of Water Resources. University of Arizona Cooperative Extension. Study estimates economic impacts of drought and drought-induced land fallowing on crop insurance indemnity payments, forage production for grazing, and crop production. Commissioned by Arizona Department of Water Resources (ADWR) staff for their planning purposes, and to gain a comprehensive sense of how drought affected different segments of agriculture statewide. ADWR made recordings of our briefings on the report for internal circulation and use. Investigators were invited to make presentations for ADWR to brief staff on main findings.

Duval, D., A.K. Bickel, and G. Frisvold. 2021. The Costs of Wildfire in Arizona: A Survey of Methods, Data, and Estimates. Final Report to the Arizona Department of Water

Resources. University of Arizona Cooperative Extension. For the Arizona Department of Water Resources (ADWR), and Arizona Department of Forestry and Fire Management (ADFFM). Information on the nature and magnitude of wildfire costs in Arizona had been scattered across different government databases, publications, and gray literature. This report provides information about wildfire costs in the state over the past 20 years. ADWR has shared report with other state agencies. ADWR has begun to organize further collaboration between us and ADFFM.

Presentations: Agriculture and Drought in Arizona. Presentation for the State Drought Monitoring Technical Committee (MTC). April 2022. ADWR wanted to disseminate the results of our report more widely.

Economic Effects of Drought and Fire. Presentation for ADWR working on drought response policy. April 2022. ADWR wanted to us to answer questions about our written final reports. ADWR requested that they record our presentation to share with staff. They also shared results with other state agencies and drought organizations.

Media citations: Kann, D., R. Rigdon, and D. Wolfe. [The Southwest's Most Important River is Drying Up](#). CNN. August 21, 2021.

Kruzman, G. [US Southwest, already parched, sees 'virtual water' drain abroad](#). Grist. June 5, 2021.

Moran, G. [Could Climate Change Put an End to Arizona's Alfalfa Heyday?](#) Civil Eats. September 15, 2021.

Impacts: At the statewide Agribusiness & Water Council of Arizona's annual meeting and water conference, our research on the economic impacts of Colorado River Shortage declarations on state agriculture were the most cited body of research among speakers.

We developed good working relationships with staff at the Arizona Department of Water Resources and Arizona Parks and Trails. They have been supportive both financially and in terms of promoting our research findings to other stakeholders statewide.

Stakeholders used results of our research findings to request and successfully receive \$10 million in water infrastructure funding from USDA.

An Assessment of Drought and Climate Vulnerability and Resilience in the Rio Grande Basin in New Mexico

CLIMAS Investigators: C. Greene, D. Ferguson, and B. McMahan

End Users: New Mexico Drought Monitoring Working Group

Populations Benefited: Research aims to inform equity and drought monitoring and identifying underserved communities impacted by drought in New Mexico, such as Tribes and Pueblos, and small-scale or subsistence farmers in rural New Mexico.

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.

Urban Heat and Health Interventions and Evidence Gaps (Extension of CLIMAS Urban Heat Island Mapping project)

CLIMAS Investigators: L. Keith and E. Schmidt

Research Partners: NOAA Climate Program Office; City of Tucson, AZ; Pima County, AZ; City of Seattle, WA; King County, WA; City of Houston, TX; Harris County, TX; City of Baltimore, MD; Baltimore County, MD; City of Detroit, MI; Wayne County, MI

End Users: Urban planners, landscape architects, emergency managers, public health officials, sustainability/resilience staff, and climate service providers

Additional Support: NOAA Climate Program Office

Abstract: Extreme heat is an increasing climate risk that lacks the governance and legal structure that other climate risks like wildfire, urban flooding, drought, and sea level rise have. Better understanding the emerging governance of extreme heat risk will help improve climate services for local decision-makers. This study will provide an in-depth investigation of the survey results on how communities plan and govern extreme heat risk. The case study methods include semi-structured inter-

views with decision-makers and content analysis of plans for heat management and mitigation strategies. It builds upon the work started with the CLIMAS Urban Heat Island Mapping project that assessed the use of UHI maps and decision-making in the Southwest, a literature review on planning for extreme heat, and the survey of U.S. planners on extreme heat. To document the current state of emergent extreme heat governance in the U.S., five case study communities were selected, including Tucson, AZ; Houston, TX; Baltimore, MD; Detroit, MI; and Seattle, WA. These communities represent five National Climate Assessment regions; four of the communities participated in the NIHHS-CAPA Heat Mapping Campaign.

Findings: Planners are currently siloed in heat governance and comprehensive plans in the communities studied do not yet adequately address heat.

Outputs

Publications: Keith, L., S. Meerow, D.M. Hondula, V.K. Turner, and J.C. Arnott. 2021. Deploy heat officers, policies, and metrics. *Nature* 598(7879):29-31. Heat governance is less mature than governance structures, processes, and actors for other climate risks. Calls for more research and policy focus on heat governance.

<https://doi.org/10.1038/d41586-021-02677-2>

Meerow, S. and L. Keith. 2021. Planning for extreme heat: A national survey of U.S. planners. *Journal of the American Planning Association*. We conducted a survey of planners across the U.S. in communities of diverse sizes and geographies to document current heat planning efforts, information uses, and challenges. First national survey of heat planning in U.S. and establishes a baseline of current heat planning efforts. Cited by two academic papers and the Centering Equity to Address Extreme Heat report by the Urban Institute.

<https://doi.org/10.1080/01944363.2021.1977682>

Keith, L. and S. Meerow. 2022. Planning for Urban Heat Resilience. Planning Advisory Services (PAS) Report 600. American Planning Association. In the American Planning Association's 600th guidebook in the Planning Advisory Service series, Keith and Meerow outline practical steps communities can take to understand and advance their urban heat resilience efforts. This is the first comprehensive guide for heat planning published by the American Planning Association. The NCA may use the heat planning framework we outline for the NCA urban chapter.

<http://www.planning.org/publications/report/9245695/>

Media Articles: Keith, L. and A.K. Gerlak. 2021. [There's no place in the US safe from the heat.](#) August 20, 2021.

Keith, L. and S. Meerow. 2021. [Cities must plan for heat resilience now.](#) Thomson Reuters Foundation. July 5, 2021.

Keith, L. and S. Meerow. 2021. [Beat Extreme Heat with these 8 Tactics.](#) Planning Magazine. Winter 2021:12-14.

Presentations: Planning for Urban Heat Resilience. *SPAN Lecture Series*. Southwest Practitioners Adaptation Network (SPAN). May 2022.

Geospatial Online Tools for Public Participation Demonstrations." *Mapping the Way Ahead: Online Geospatial Tools for Public Participation*. University of Arizona, Udall Center. Washington, D.C. May 2022.

Community Perspectives: Roundtable discussion with state and local partners to understand current priorities and challenges in heat resilience planning. *National Integrated Heat Health Information Systems (NIHHIS) National Meeting*. NIHHIS. April 2022.

6th Annual Arizona Extreme Heat Planning Workshop. Arizona Department of Health Services, National Weather Service, Arizona State University, and University of Arizona. April 2022.

City of Tucson Climate Action and Adaptation Plan. *Drachman Institute Relaunch*. University of Arizona. Tucson, Arizona. April 2022.

Planning for Extreme Heat. *Lifelong Learning in Retirement at the Highlands*. The Highlands at Dove Mountain. Marana, Arizona. February 2022.

Planning for Extreme Heat & Equity. *First Annual Symposium*. American Planning Association (APA) Sustainable Communities Division (SCD). January 2022.

Best Practices for Cross Governmental and Interdisciplinary Collaboration to Advance Heat Governance. *Southeast Florida Regional Climate Change Compact's Virtual Workshop*. November 2021.

National Perspectives to Local Applications. *City of Tucson 12th Urban Heat Island Workshop*. November 2021.

Prioritize and Integrate Heat Planning. *National Integrated Heat Health Information Systems (NIHHIS) Urban Heat Island Community of Practice Webinar Series*. NOAA. October 2021.

Plan Integration and Governance. *NOAA Climate and Equity Roundtable: Heat Resilience in the U.S. Southwest*. NOAA. October 2021.

Extreme Heat and Climate Justice. *American Collegiate Schools of Planning 2021 Annual Conference*.

October 2021.

Planning for Urban Heat Resilience. *SGDE Colloquium Series*. University of Arizona, School of Geography, Development and Environment, Tucson, Arizona. September 2021.

Keeping Homes and Cities Cool: Heat Governance. *Arizona Senior Academy*. Academy Village. Tucson, Arizona. September 2021.

Creating Cooler Homes and Schools. *Climate Adaptation Research Symposium 2021*. UCLA Luskin Center for Innovation. Los Angeles, California. September 2021.

Urban Heat Resilience. *Wonder at Home*. University of Arizona Foundation, Tucson, Arizona. July 2021.

Addressing Climate Risk through Equitable Community Development. Federal Reserve Bank of San Francisco. San Francisco, California. Virtual. July 2021.

Integrating energy justice with community climate action planning. *EGU General Assembly 2022*. European Geosciences Union (EGU). Vienna, Austria. May 2022.

The Effect of Vehicles on Personal Heat Exposure: A Pilot Study. (Poster) *Annual Meeting of the Transportation Review Board*. Transportation Review Board. Washington, D.C. January 2022.

Framing urban heat governance through five case studies. *American Collegiate Schools of Planning 2021 Annual Conference*. American Collegiate Schools of Planning. October 2021.

Social Media: Active on Twitter @laddkeith and LinkedIn

Media citations: Parsons, D. [Planning for Urban Heat Resilience with Dr. Ladd Keith and Dr. Sara Meerow](#) America Adapts: The Climate Change Podcast. May 9, 2022.

Murphy-Darling, G. [It is Getting Hot in Here – Building Resilience to Address Extreme Heat.](#) Mrs. Green's World. March 7, 2022.

LeRoy, S. [Extreme Heat & Urban Planning.](#) Come Rain or Shine Podcast. September 1, 2021.

Parsons, D. [Extreme Heat in the News, Naming Heat Waves, Thermal Equity and more with Dr. Ladd Keith.](#) America Adapts: The Climate Change Podcast. July 5, 2021.

Antoniou, L. [Urban heat is an invisible threat – resilience against it shouldn't be.](#) SmartCitiesWorld. May 27, 2022.

Elbein, S. and S. Udasin. [Equilibrium/Sustainability – Texans cut off.](#) The Hill. May 10, 2022.

Vock, D.C. [How Cities are Trying to Combat the Nation's Deadliest Weather Risk.](#) Route Fifty. April 26, 2022.

Elbein, S. and S. Udasin. [Equilibrium/Sustainability - Cities need to do more to confront deadly heat: study.](#)

The Hill. March 25, 2022.

Ramirez, J. [Tucson pushes toward climate action goal.](#)

KOLD News 13. February 17, 2022.

Brodie, M. [City planners have tools to deal with heat. A new survey finds many may not be using them.](#) KJZZ's The Show. February 4, 2022.

Smith, D. [What's old is new again.](#) Hothouse Solutions. November 29, 2021.

Devera, J. [Will More Cities Hire a Chief Heat Officer?](#) NBC LX. November 24, 2021.

Brey, J. [Facing Our New Climate Reality.](#) Dwell Magazine. November 16, 2021.

Smith, D. [Should air conditioning be a human right?](#) Hothouse Solutions. November 16, 2021.

Staletovich, J. [South Florida is getting hotter. But planners say there's a data gap in finding solutions.](#) WLRN's The Daily. November 10, 2021.

Blaze Baum, K. and M. McClearn. [Extreme, deadly heat in Canada is going to come back, and worse. Will we be ready?](#) The Globe and Mail. September 25, 2021.

Brodie, M. [No Safe Place On The Planet From Heat: Extreme Heat Is Becoming National Issue.](#) KJZZ's The Show. September 9, 2021.

Tucker-Smith, O. [Neighbor wasting water? Is 'water shaming' the answer?](#) The Salt Lake Tribune. July 21, 2021.

O'Donnell, T. [How will cities adapt to extreme heat?](#) The Week. July 12, 2021.

Quinn, D. [Protecting yourself during extreme heat.](#) KVOA News 4. July 1, 2021.

Mittan, K. [Keeping Homes and Cities Cool in Extreme Heat.](#) University of Arizona, University Communications. June 23, 2021.

Ramirez, J. [MONSOON 2021: Hiking in heat can have deadly repercussions in southern Arizona.](#) KOLD News 13. June 14, 2021.

Advisory Role: Management Committee Member for the Global Heat Health Information Network (GHHIN) – sponsored by the UN, WMO, and WHO.

New Funding Acquired: Plan Integration for Resilience Scorecard for Heat (PIRSH). NOAA. (\$147,474); 6/2021-5/2023. With Sara Meerow, ASU (Co-PI), Joseph DeAngelis, American Planning Association (Co-I), Philip Berke, UNC (research personnel), Cities of Houston, Ft. Lauderdale, Boston, Baltimore, Seattle, and King County WA (community partners)
Assessing Cool Corridor Heat Resilience Strategies for Human-Scale Transportation. U.S. Department of Trans-

portation and the National Institute for Transportation & Communities (\$75,000), 10/2021-12/2022. With Kristi Currans and Nicole Iroz-Elardo (Co-PIs); City of Tucson Department of Transportation (community partner)
NITC Diversity Grant Extension for Cool Corridors. U.S. Department of Transportation and the National Institute for Transportation & Communities (\$5,000), 5/2022-8/2022. With Kristi Currans and Nicole Iroz-Elardo (Co-PIs); UA Parking & Transportation (community partners)
Building Resilience Against Climate Effects (BRACE). U.S. Centers for Disease Control. (\$2 million total, \$450,000 to UArizona), 2022-2026. With Heidi Brown (UA PI), Erika Austhof (personnel), ADHS (grantee), ASU (co-awardee), Pima County Department of Health and Maricopa County Department of Health (community partners)
Cool Kids, Cool Places, Cool Futures: Community-based, arts-enhanced, and Youth Focused Approach for Equitable Urban Cooling and Emergency Management. Robert Wood Johnson Foundation (\$584,886 total, \$4,000 to UArizona), 2022-2023. With City of Tempe and ASU (grantee), Braden Kay (PI), Katja Brundiers and Paul Coseo (Co-Is)
Climate Action and Adaptation Plan, Climate Consulting Services Proposal. City of Tucson (\$13,013 to UArizona through subaward), 2022. With Buro Happold (consultant), City of Tucson (funder/partner)

Visualization & Analysis Tools for the North American Monsoon – Integrating Citizen Science Data and Observations

CLIMAS Investigators: B. McMahan; M. Crimmins

Additional Investigators: R. Granillo, M. Herrera, B. Delgado, C. Larsen, D. Hoy, Arizona Institutes for Resilient Environments & Societies, University of Arizona

Research Partners: National Weather Service Tucson

End Users: National Weather Service Tucson and Phoenix offices; NWS Regional Climate Services Director; County Flood Control Districts; Pima County Office of Emergency Management; Oro Valley Police Dept. Municipal/Irrigation Outreach group; Pima County Natural Resources Division; National Phenology Network (NPN)

Populations Benefited: Tucson AZ, Phoenix AZ, Mojave County, Pinal County, Maricopa County

Additional Support: NOAA National Weather Service (NWS); Arizona Institutes for Resilient Environments & Societies; AZ Department of Water Resources

Abstract: Monsoon precipitation is difficult to forecast and

analyze. Daily and seasonal precipitation are commonly used, but other sources of data (including citizen science monitoring) could be integrated into a higher resolution and more accurate monsoon assessment framework. Tucson has dozens of observations collected by these networks, along with datasets based on radar and weather models. A central monsoon data repository would form a dense network of observations, facilitate innovative visualizations, and offer an unparalleled high-resolution view of regional precipitation patterns. This would also pilot-test a process by which southwestern data networks could be combined into an integrated monsoon assessment database. In January 2021, AIREIS funded the monsoon fantasy game, an extension of this project and the podcast.

Findings: As expected and generally assumed, the monsoon is highly variable across even small geographic areas, like Tucson metro area and Pima county. The data and visualizations derived from this project illustrate this variability on a daily/event basis and inform seasonal monsoon tracking that considers how these variations play out in small regions. The station data we aggregated is facilitating a grid (MRMS/PRISM) vs. station data analysis of daily precipitation totals to highlight this variability and assess the correspondence and accuracy between station observations and grid-based estimates.

Outputs

Data: Monsoon data aggregator/NWS tracker. Integrates station data and CLIMAS/Crimmins maps for daily and seasonal monsoon tracking. <https://www.weather.gov/twc/Monsoon>
Existing monsoon tracker was updated to include Mojave data, provided in collaboration with ADWR. Mojave is data black hole despite being well instrumented with FCD stations. Working to expand to other rural counties in AZ. <https://monsoon.environment.arizona.edu/>

Presentations: Exploring Monsoon Season and Current Weather Conditions with CLIMAS – Sky Island Alliance Series, July 2021.

Monsoon Monitoring Tools from CLIMAS – NIDIS Southwest Drought Briefing: August 2021. Stakeholders wanted an update on SW conditions and tool.

Other: Monsoon Fantasy Game, an online game to promote monsoon education and outreach. Resulted in lots of community engagement and media coverage. <https://monsoonfantasy.arizona.edu/home>

Media Citations: Kelley, M. [Monsoon Madness: Professional and Amateur Forecasters Invited to Bet on Much-Need-](#)

[ed Rain](#). June 15, 2021.

Ramirez, J. [University of Arizona researchers create “Monsoon Madness” game](#). June 20, 2021.

Goldstein, S. and M. Brodie. [Monsoon Madness: Arizona Researchers Create Fantasy Monsoon Game To Spread Awareness About Climate Change](#). June 28, 2021.

Graf, N. [UArizona researchers develop fantasy sports-style game aimed to predict Monsoon 2021 rainfall](#). June 27, 2021.

Wegleitner, T. [UA creates ‘Monsoon Fantasy’ game](#). July 9, 2021.

Perkins, T. [Game challenges forecasters to predict monsoon](#). June 23, 2021.

Kutz, J. [A monsoon summer in the Southwest](#). September 17, 2021.

Impacts: Developed a daily monsoon visualizer based on input from NWS Tucson and other local stakeholders. NWS Tucson revised their monsoon tracker with input and maps from CLIMAS, resulting from monthly meetings between NWS personnel and CLIMAS leading up to June 2022. NWS Tucson serves the southern Arizona region which includes over a million residents. The visualizer’s best coverage is limited to the Tucson Metro Area but plans to scale this work into rural areas across Arizona are developing, in partnership with ADWR. Update with NWS tracker provides information and decision support to TUS and PHX NWS weather offices, servicing ~5M in Phoenix metro, 1M in Tucson metro, along with numerous other smaller/rural communities across the TUS and PHX weather offices. We expanded data coverage to rural areas, starting with Mojave county, based on requests to build out the dataset and provide API to curate ADWR data that is not otherwise available.

Expanded scope and relationship with ADWR from curating data for locations not well organized to date (in Mojave, for example). Added value to their data by providing a data repository for long term use and storage for our own internal visualization and analysis, and for distribution via data API.

Collaborative Research on Environmental Risks and Built Environment in the Borderlands of the Southwest

CLIMAS Investigators: B. McMahan, R. Driesen, L. Pilli, and M. Moeller

Research Partners: NOAA – National Weather Service Tucson; Environmental Protection Agency – Border

Environment Cooperation Commission/Border 2020; AZ Department of Environmental Quality; Asociación por Revegetación en Ambos Nogales (ARAN); Sonora Environmental Research Institute; Borderlands Restoration

End Users: Environmental Protection Agency – Border Environment Cooperation Commission/Border 2020; Schools and teachers in partner network in Ambos Nogales; Centro de Capacitación para el Trabajo Industrial (CECATI); Instituto Tecnológico de Nogales (ITN); Universidad Tecnológica de Nogales (UTN)

Populations Benefited: Ambos Nogales: Nogales, AZ (85621) and Nogales, Sonora, Mexico (84000, 84065, 84094, 84097). Students, faculty, (HS, university, technical college) and community collaborators in US/Mex borderlands region.

Additional Support: Agnese Nelms Haury Program, University of Arizona; Environmental Protection Agency – Border Environment Cooperation Commission/Border 2020

Abstract: This project provides a mechanism to develop new research and engagement in the border region and to connect CLIMAS expertise to existing work. Nogales has actively grappled with numerous environmental challenges. Our collaboration added a climate information and decision support element to ongoing collaborative efforts. We contributed to a solar feasibility project, culminating in an EcoCasa web launch and environmental workshops.

Climate information and impacts presentations became routine at both ITN and UTN. ITN/UTN faculty wanted to integrate climate information into their technical training programs and asked us to present to specific classes or to all-school assemblies.

Impacts: Provided climate information, education, and outreach to hundreds of high school, university, and technical students as part of classroom curricula and assembly or workshop presentations. Led technical workshop for a few hundred students on use of small-scale sensors for tracking local air quality. EcoCasa website is a hub of environmental info and education focused on specific projects and themes, such as climate education and solar potential.

Rethinking Social Vulnerability: Climate Risks and Impacts

CLIMAS Investigators: B. McMahan, R. Driesen, L. Pilli, M. Moeller, and C. Cheung

Research Partners: Bureau of Applied Research in Anthropology (BARA); Sonora Environmental Research Institute (SERI)

Populations Benefited: 85713, 85711, 85714, 85706, Tucson, AZ. We will expand the heat tool to Maricopa County and urban Phoenix, based on a request from National Weather Service, Phoenix. Low income and Latinx households in South Tucson.

Additional Support: Bureau of Applied Research in Anthropology (BARA), University of Arizona; Sonora Environmental Research Institute (SERI); Agnese Nelms Haury Program, University of Arizona; NOAA National Weather Service (NWS)

Abstract: Challenges exist in understanding climate-related social vulnerability and climate related impacts, especially in marginalized groups or underserved populations. This type of vulnerability must expand beyond demographically determined assessments, which often veer towards geographic determinism, or simply describing the underlying inequalities that are amplified by climate. This project seeks to better define social vulnerability to climate and the intersection of acute impacts and chronic conditions that further amplify these vulnerabilities. Current activities focus on energy equity and thermal comfort in Tucson neighborhoods (in collaboration with BARA and SERI, and funded by Haury) and developing improved characterizations of urban heat and air quality maps (an extension of Haury-funded activities).

Findings: Solar powered minisplits are effective – if a little overcomplicated – at providing supplemental heating and cooling without the cost and complication of whole house solar.

Existing heat maps based on satellite images are insufficient for providing neighborhood scale decision support and temperature risk assessments, while single station data lacks information on microclimate and thermal comfort and experience. The heat mapping project prototype developed through this project is informed by conversations and priorities expressed in internal CLIMAS/NWS planning meetings.

Outputs

Presentations: Collaboration, Climate Services, and Tools for Decision Support: Three Examples of Applied

Research Tailoring Weather and Climate Information for a Utility in the Southwestern United States. American Geophysical Union. December 2021.

Improving Equity in Solar Access in Arizona. Equity in Financing and investment – SOLAR 2022: Energy Transition with Economic Justice – American Solar Energy Society. June 2022.

Using Sensor, Climate and Household Thermal Comfort Data to Evaluate the Effectiveness of Solar Powered Mini-Split Units. **Equity in Financing and investment – SOLAR 2022: Energy Transition with Economic Justice – American Solar Energy Society. June 2022.**

Impact: We developed a prototype project to gather temperature data from a variety of sources (e.g., satellite, sensor data, backyard weather stations) to build multi-temporal heat profiles that provide more granular spatial details on location of heat extremes. This is ongoing. NWS Tucson and NWS Phoenix Science and Operations Officers are both very enthusiastic on anything we can develop that enhances heat mapping by providing additional temporal or spatial detail. Current data is limited to either station observations or coarse measures that use satellite images that are not locally accurate.

Community Climate Profiles

CLIMAS Investigators: A. Meadow, J. Weiss, L. Keith, and S. Leroy

End Users: PROTECT campaign, Prescott City Council; City of Sedona, AZ; Pueblo of Laguna, NM; Arizona Land and Water Trust; City of Flagstaff, AZ; Tohono O’odham Nation – Office of Emergency Management; The Highlands at Dove Mountain

Populations Benefited: Prescott, AZ; Yavapai County, AZ; Flagstaff, AZ; Oro Valley, AZ; The Highlands at Dove Mountain, Marana, AZ; Pueblo of Laguna, NM; Gila River Indian Community, AZ; Sedona, AZ

Additional Support: Adaptation International

Abstract: Although this project ended, A. Meadow was recently invited by PROTECT, a community group in Prescott, who is interested in a climate profile. They are now in the early stages of negotiating a climate profile for City of Prescott, who is considering developing a climate action plan and would use the profile as technical input into their planning process.

Outputs

Presentations: Prescott City Council Work Session. About 10 City Council members and staff and 15 members of

the public. April 2022. Meadow was invited by the City Council after the citizen group PROTECT asked them to invite her.

Impact: Sedona, AZ has moved ahead with a climate action planning process, using the climate profile as a foundation.

Building Regional Food System Resilience in Southern Arizona – Learning from COVID-19

CLIMAS Investigators: G. Owen, S. Renkert, E. Kinkaid

Additional Investigators: L. Bellante, University of Arizona – Center for Regional Food Studies

Research Partners: Pima County Food Alliance

End Users: Pima County Food Alliance; Arizona Food Systems Network

Populations Benefited: Pima County farms and food businesses

Additional Support: NOAA Climate Program Office - Business Disruption and Resilience in the Context of Complex Climate Events; Coverdell Fellowship; Arizona Institute for Resilient Environments and Societies; Pinnacle Prevention; Community Food Bank of Southern Arizona

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. In summer 2021, we partnered with Pima County Food Alliance (PCFA) to gather more information about food system needs and opportunities through a series of focus groups and farmer interviews. This was in support of efforts of the Arizona Food Systems Network’s development of a statewide food system plan. Because of our collaboration on these focus groups, PCFA asked us to write a grant with them to the Community Food Bank of Southern Arizona to help revitalize the food council. We have made an official partnership between PCFA and the food systems research lab through summer 2023. The lab will provide research, facilitation, and evaluation assistance in support of the PCFA’s efforts.

This next year we will continue our partnership with PCFA. We will work to develop the community liaison

program and evaluate the impact/success of their efforts over the course of the Thriving Communities grant. We hope to build community partnerships across Pima County and begin advocacy campaigns for equitable food policy in Tucson and other cities.

Outputs

Publications: Bellante, L., M.A. 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):1-3. This brief paper explains the project and partnership we've built with PCFA. [doi:10.5304/jafscd.2022.113.017](https://doi.org/10.5304/jafscd.2022.113.017)

Media: Kinkaid, E., G. Owen, and L. Bellante. 2021. [Tucson Opinion: COVID-19 impacts demonstrate why Southern Arizona needs more farmers.](#) *Arizona Daily Star*, July 17, 2021.

Project Website: Food Systems Research Lab: Researching, convening, and advocating for positive food systems change in southern Arizona.

<https://crfs.arizona.edu/food-systems-research-lab>

Workshops: Series of focus groups in fall 2021 with 1) farm to institution group; 2) food distribution group; and 3) food access organizations to collect information about how the pandemic impacted their operations, lessons learned, opportunities, and needs. 4-7 participants per group.

Presentations: The State of State and Local Food Systems during COVID-19: Lessons Learned and Opportunities for Growth in Stakeholders, Governance, and Community Engagement. Annual meeting of the Agriculture, Food, and Human Values Society and the Association for the Study of Food and Society. Virtual. May 2022. Impacts of COVID-19 on Pima County's Food System. Pima County Cooperative Extension Advisory Board. Tucson, AZ. March 2022.

Media appearances: [Food Systems: Pandemics, Equity, and the Future.](#) Mrs. Green's World Podcast. January 24, 2022.

Advisory Role: Formal advisory role with Pima County Food Alliance

New Funding Acquired: Pinnacle Prevention Supplemental Funding (\$4,000) and Thriving Communities Grant, Community Food Bank of Southern Arizona: Cultivating Equitable Food Policy in Pima County (\$60,000). Co-PI with Shelby Thompson from the Pima County Food

Alliance. The Pima County Food Alliance asked us to collaborate with them on this proposal. We are serving as the research arm of the PCFA and working to help them build capacity and membership to address multiple food system issues in Pima County.

The Influence of Climate on Lower Colorado Streamflow Variability: Present, Past, and Future

CLIMAS Investigators: C. Woodhouse, D. Ferguson

Additional Investigators: B. Udall, Colorado State University; A. Gerlak, School of Geography, Development, and the Environment, UArizona

End Users: R. Doba, Principal, Ron Doba Management Services LLC; M. Mahmoud, Senior Policy Analyst, Central Arizona Project; K. Mott Lacroix, Hydrologist, US Forest Service; B. Svoma, Meteorologist, Salt River Project; E. Young, E. Schenk, and B. Hill, Flagstaff Water Services

Abstract: This study evaluates the seasonal climatic components that control surface water supplies in the lower Colorado basin, with a specific focus on the Gila River and the influence of temperature on annual streamflow in recent decades. The project investigated questions and produced scientific results meaningful and useful for decision makers in the LCRB. The project team identified interested resource management partners in the LCRB to help shape a research agenda that addressed climatic controls on surface water supplies in the lower basin in a way that is relevant to resource management. We began dialogue in late summer 2018 with a small group (10-12) of potential research partners to identify research questions, followed up with a webinar in spring 2019, and have continued to work with a subset of these partners on topics of interest (e.g., Flagstaff Water, SRP, and CAP).

Findings: No significant decreasing trends in annual streamflow in the upper Gila, Salt and Verde Rivers are evident despite warming temperatures, although decreases are evident in autumn and spring streamflow.

While cool season precipitation is the most important climatic variable for annual streamflow, summer temperatures are also important, and the influence of monsoon precipitation is also discernable in certain years.

Outputs

Data: Seasonal climate and streamflow datasets for the upper Gila, Salt, and Verde Rivers, available on the project [website](#), under the Catalogue of Years section.

Publications: Woodhouse, C.A. and B. Udall. 2022. Arid land

rivers in a changing climate. *Earth Interactions* 26:1-14. This research investigates the climatic controls on the Gila River and its major tributaries, the Verde and Salt Rivers, to gain insights on how trends in climate may impact future water supply. The paper is a response to the need for a citable source of information on the effects of climate on Salt and Verde River water supplies voiced by our stakeholder advisory group. Received invitations to present findings at the Phoenix Chapter of the Arizona Hydrologic Society by one of our advisory members in April, at the annual Arizona Hydrologic Society meeting in a session hosted by the Salt River Project (September 2022), and at Salt River Project's climate change conference in October 2022.

<https://doi.org/10.1175/EI-D-21-0014.1>

Project Website: [Arid Lands Rivers in a Changing Climate: The Upper Gila, Salt, and Verde Rivers](#). This project web site contains information on the project, the collaborative process, an overview of the upper Gila Basin, fact sheets, a catalogue of unusual years, and links to project outputs.

Presentations: Climate and Streamflow in the Upper Gila, Salt, and Verde Rivers: Relationships and Trends. Phoenix Chapter of the Arizona Hydrological Society. April 2022.

Impact: The publication of a peer-reviewed paper on climate and streamflow relationships in the upper Gila, Salt and Verde Rivers was requested at the onset of the project by our management advisory group, who indicated that citing this would be useful to their work.

Transdisciplinary Environmental Science for Society (TESS) Professional Development Program

CLIMAS Investigators: C. Woodhouse, D. Ferguson, G. Owen

Additional Investigators: G. Garfin, UArizona School of Natural Resources and Environment; M. Ramirez-Andreotta, UArizona Environmental Science; UArizona Office of Digital Learning; UArizona Continuing and Professional Education

End Users: Professionals and graduate students who want a solid grounding in collaborative research approaches.

Abstract: 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 ad-

vances, higher educational systems traditionally have not trained students to work across these gaps. To address this shortcoming, we designed the TESS Program. This three-part online professional development series equips future generations of researchers, practitioners, political leaders, and educators to actively confront society's most complex environmental challenges. Courses were offered throughout 2021 and 2022. These courses are now being combined and re-designed for a 1-unit graduate course for the Global Change minor at UArizona.

Outputs

Project Website: [TESS: Transdisciplinary Environmental Science for Society](#)

Curricula: Three 4-week online course curricula developed:

1. Fundamentals of Transdisciplinary Research;
2. Practicing Collaborative Research;
3. Communication Strategies for Collaboration.

