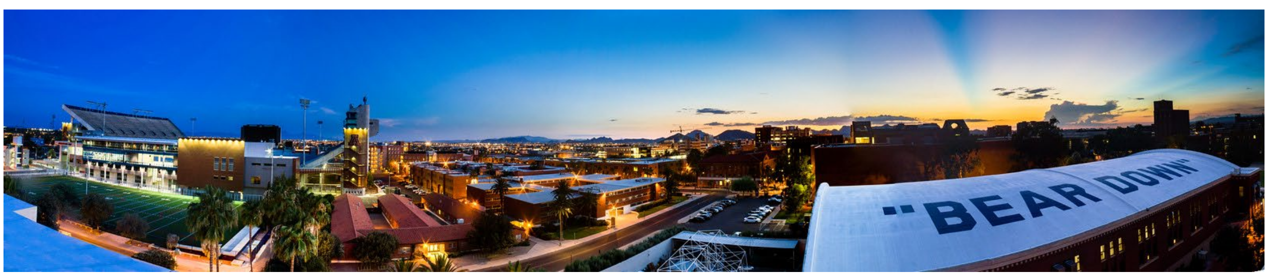
THE UNIVERSITY OF ARIZONA | FOCUS ON ENVIRONMENT AND ECOLOGY MAGAZINE | SUMMER 2022

FOCUS ON ENVIRONMENT & ECOLOGY

UNIVERSITY OF ARIZONA LAND ACKNOWLEDGMENT

We respectfully acknowledge the University of Arizona is on the land and territories of Indigenous peoples. Today, Arizona is home to 22 federally recognized tribes, with Tucson being home to the O'odham and the Yaqui. Committed to diversity and inclusion, the University strives to build sustainable relationships with sovereign Native Nations and Indigenous communities through education offerings, partnerships, and community service.



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SENIOR VICE PRESIDENT FOR RESEARCH AND INNOVATION

With increasingly frequent extreme heat, wildfire and drought, the arid southwestern United States serves as a testbed and harbinger for the rest of the globe if climate change goes unaddressed. According to EPA data, every part of the Southwest experienced higher-than-average temperatures between 2000 and 2020. The Colorado River Watershed, which provides drinking water to 40 million people across seven states, is in the middle of a historic 22-year drought. Wildfires have become more intense and persistent, scorching significantly more acreage than in decades past and putting fragile ecosystems at risk.

To protect our environment and pave the way for a brighter, more resilient future for all of us, science underpinned by curiosity, innovation, determination and compassion is critical. That is why University of Arizona researchers and students — who embody these important traits — are harnessing the power of place. Working here in the heart of the Sonoran Desert, they are leading the way toward meeting today's challenges — and those of tomorrow.

We exist not only to educate: the university's land-grant mission has tasked us with service to Arizona and beyond. Within the pages of this magazine, we offer glimpses into our mission in action. Read about steadfast, forward-thinking UArizona researchers and students who are mitigating the impacts of extreme heat; informing policymakers on how to reduce poverty and hunger with real-world, multipronged solutions; promoting Indigenous environmental scholarship and sovereignty; and even exploring how to build hardier, more adaptable coral reefs. Collectively, these stories illustrate our ability to convene great minds and tackle the most pressing, complex challenges of the 21st century.

Explore our work in environmental science and policy in depth at ***research.arizona.edu***.

Eliz R Cantwell

Elizabeth Cantwell, PhD, MBA
Senior Vice President for Research and Innovation

NEW LEADERSHIP FOR AIRES

WELCOMING SHARON COLLINGE

"I deeply appreciate the bold vision of those involved in the development of AIRES to promote connections and knowledge creation that support resilient environments and societies. My goal is to continue to build on and expand the impact of innovative research, education and community engagement activities that are the core of AIRES programs and to amplify the reach of the University of Arizona."

Sharon Collinge, president-elect of the Ecological Society of America and former chief scientist and observatory director of the National Ecological Observatory Network, joins the University of Arizona as director of the Arizona Institute for Resilient Environments and Societies (AIRES) in August.

In her 24 years with the University of Colorado – Boulder, Collinge served as director of the undergraduate and graduate programs in environmental studies and led the university's planning for a campus-wide structure for sustainability. Studying human-environment and ecosystem interactions, Collinge's teaching and research intersects environmental policy, planning and habitat protection and restoration.

AIRES brings together faculty, students and community partners as the umbrella organization for many UArizona initiatives, including the Agnese Nelms Haury Program in Environment & Social Justice, the Center for Climate Adaptation Science and Solutions, the Desert Laboratory on Tumamoc Hill and the Indigenous Resilience Center.

With the ultimate goal of helping individuals, businesses and communities manage risk and find opportunities associated with solving the climate crisis, AIRES also helps UArizona's work toward an anti-racist and more equitable society by pursuing solutions to environmental problems rooted in social, racial and environmental justice.

DREDGED FOSSILS SHOW GLOBAL WARMING AT A 24-MILLENNIA PEAK

Geoscientists used novel data analysis to unlock a better understanding of climate — 24,000 years ago and today.

Jessica Tierney is an associate professor of geosciences and lead author of the most recent Intergovernmental Panel on Climate Change report on the physical science of climate change. She was recently named a recipient of the NSF's Alan T. Waterman Award, the nation's highest honor for early-career scientists and engineers, and is the first climatologist to receive the award since Congress established it in 1975.

Matthew Osman is a postdoctoral research associate at the UArizona Climate Systems Center, where he studies climate change across annual- to centennial-timescales. His work often combines modern observations, physical models and climate simulations with innovative data extraction from natural sources such as ice and sediments.

The multicorer device being lowered into the ocean takes eight one-foot cores from the seafloor. Scientists analyze such cores for clues to the climate of the past several thousand years. UA News

In one of the most important recent contributions to climate science, Jessica Tierney and the research team she leads nailed down the average global temperature of the last ice age, a period 20,000 years ago when vast sheets of ice covered much of Asia, Europe and the Americas.

The team at the Organic Geochemistry Laboratory made the discovery by bringing a new data source to climate modeling, which has largely relied on recorded historical temperatures. While these models account for modern climate changes, they haven't matched climates evidenced by prehistoric geologic sources.

To address that glitch, Tierney and her team developed novel methods for deducing sea-surface temperatures from ancient plankton fossils. They then combined that data with established climate simulations.

That same innovation drove another recent finding: the rate of global warming over the past 150 years is higher than at any other time in the past 24 millennia. The discovery stems from global temperature maps the team created going back 24,000 years.

"The fact that we're today so far out of bounds of what we might consider normal is cause for alarm and should be surprising to everybody," says postdoc Matthew Osman, lead author for the study.

At the same time, Tierney offers a complementary point of view: "Humans got us into this, and we can get ourselves out of it as well. We definitely have the technology to limit climate change, so I'm optimistic. Science gives me hope."

Learn more at UA News
https://bit.ly/3IznoxE
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THREE CENTURIES OF TREE-RING DATA REVEAL A GROWING THREAT IN HURRICANE SEASONS

Beyond coastal winds and storm surges, increased precipitation has made inland flooding a more costly and deadly danger.

With more than three centuries of tree-ring data from the Carolinas, dendrochronologist Valerie Trouet found that the wettest tropical cyclones today dump far more rain than in centuries past, worsening inland flooding.

Meteorologists have previously had to rely on weather station records dating only to 1948 to analyze tropical cyclones. As part of a cross-university team, Trouet helped procure and study tree-ring samples spanning 319 years. The team found that annual rainfall from the wettest tropical cyclones over that span increased 2.5 to 5 inches.

While coastal winds and storm surge grab the spotlight in reporting on hurricanes, inland flooding is a deadly hazard that typically affects a much larger area. Most of the deaths linked to 2021's Hurricane Ida, for example, were caused by drowning, and flooding from the storm across nine states caused billions of dollars in damage.

Trouet's recent collaborations have also found a half-century of more variable precipitation in California — possibly a driver of the state's worsening flood/fire cycles — and periods of stunted tree growth in tropical forests, which may help explain the diminishing role of the tropics as global carbon sinks.

Learn more at UA News
https://bit.ly/3KwqJyl
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Valerie Trouet is a professor in the Laboratory of Tree-Ring Research with joint positions in the Departments of Geosciences and Hydrology and Atmospheric Sciences.

Her award-winning ***Tree Story: The History of the World Written in Rings*** is the first non-fiction book on dendrochronology for lay audiences, blending science and storytelling in topics ranging from lost pirate treasure to the role of olives in the fall of Rome.

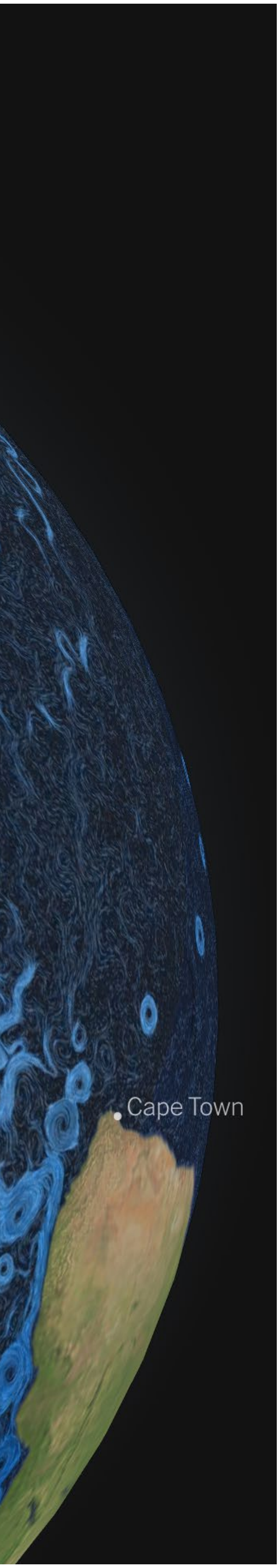
Photos: Luke Parsons

Joellen Russell is the Thomas R. Brown Distinguished Chair of Integrative Science and a geosciences professor with joint appointments in the Departments of Lunar and Planetary Sciences; Hydrology and Atmospheric Sciences; and Mathematics/ Program in Applied Mathematics. She currently serves as co-chair of the National Oceanic and Atmospheric Administration Science Advisory Board's Climate Working Group.

ICY SOUTHERN OCEAN MAY CHECK GLOBAL WARMING LESS THAN PREVIOUSLY BELIEVED

With hard-won data from waters around Antarctica, researcher Joellen Russell found the Southern Ocean may be less of a carbon sink than climate models had predicted.

Sources: Map data from the British Antarctic Survey, NASA Earth Observatory, Lamont-Doherty Earth Observatory of Columbia University, Natural Earth, Bright Earth e-Atlas Basemap



Researcher Joellen Russell knows cold and wind. She grew up north of the Arctic Circle in a fishing village and, as an oceanographer, has spent decades taking shipboard measurements at the other side of the globe, in the waters around Antarctica.

Historically, winter conditions and sea ice have made that work difficult. As a result, data sets about the Southern Ocean have been far from complete, and scientists have largely relied on computer models for a fuller picture of its conditions.

Beginning in 2014, robot floats that operate under the ice solved many of the data collection challenges. But when Russell compared shipboard measurements from 1990 to 2004 with robot measurements from 2014 to 2019, she found that actual conditions diverged significantly from what established models indicated.

Melting ice sheets had fed the waters more freshwater than modeling accounted for. Also, the ever-present westerly winds have grown more intense over the years, driving increased upwelling that pulls dense, oxygen-poor water up from deeper parts of the ocean. Together, these factors have made the Southern Ocean more acidic and warmer.

"When we correct for these known biases in the model, we can directly and beautifully reproduce what has happened over the last 30 years," Russell says.
But with that increased accuracy comes indications that today's Southern Ocean has less of a role in mitigating global warming: "We may not have as big of a carbon sink as we were hoping."

Learn more at UA News
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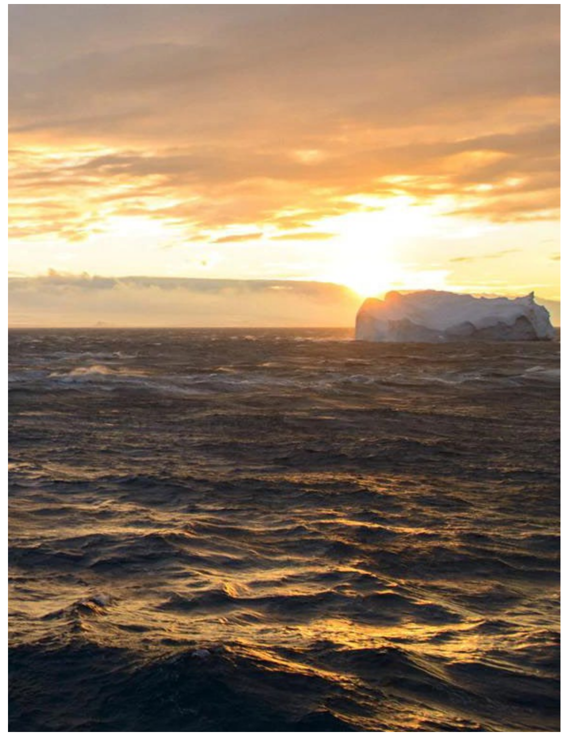


Photo: Reeve Jolliffe/CC BY-NC-ND 2.0/NASA

An Outsized Role for the World's Second-Smallest Ocean

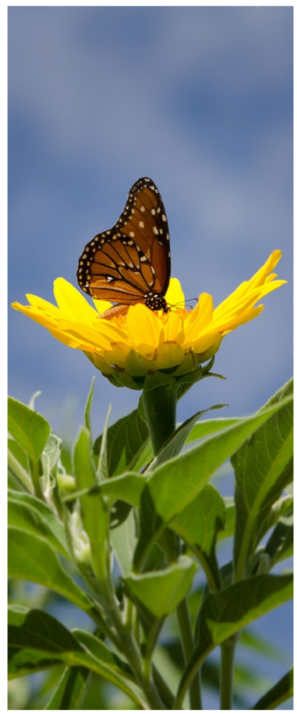
At 7+ million square miles, the body of water surrounding Antarctica, today widely recognized as the Southern Ocean, is the world's second smallest ocean but one that punches above its weight for taking CO_2 out of the atmosphere.

However, the role of ocean waters as a carbon sink is largely a function of temperature and acidity, both of which affect the health of algae, phytoplankton and other marine life that absorb carbon as part of the food web. Additionally, carbon dissolves less readily in warmer water.

As the Southern Ocean becomes both warmer and more acidic, its ability to pull and hold heat-trapping CO_2 will continue to diminish.

SHIFTING SEASONS PORTEND TROUBLE FOR LINKED SPECIES IN MUCH OF THE UNITED STATES

Changing climate has made many phenological events — from the flowering of trees to the timing of caterpillars entering cocoons — dangerously out of sync.



Theresa Crimmins is a research professor focused on phenology, the study of cyclical natural events among plants and animals.

She is the current director of the NSF-supported USA National Phenology Network, a collaboration of 500+ data-contributing partners and tens of thousands of community science volunteers. The network is hosted in the University of Arizona School of Natural Resources and the Environment.

Michael Crimmins is an Extension specialist and professor in the Department of Environmental Science.

Photos: Brian F. Powell

Research by Theresa Crimmins, in collaboration with her husband Michael, found that in the northeastern U.S., leading springtime events now occur about six days earlier than they did 70 years ago. In the Southwest, nature crosses that threshold 19 days earlier. The Southern Rockies and Pacific Northwest also now experience significantly earlier springs.

Though we define seasons based on Earth's orbit, many of the phenological events we associate with seasons, things like seed germination or animal migrations, are triggered by accumulated heat (or the lack thereof). When total heat or cold crosses certain thresholds, nature responds, and synchronized timing can be critical.

For example, pied flycatchers still migrate from Africa at the same time each year, but these birds are in decline because the caterpillars they eat on arrival in Europe now pupate earlier. Shifts in phenology threaten human food security, too: In 2017, Georgia peach trees flowered early, then frost killed some 80% of the crop. A similar phenological shuffle cost Michigan's cherry industry $200 million in 2012.

"Dramatically earlier spring activity has been documented in hundreds of species around the globe," Crimmins says. "When species that depend on one another — such as pollinating insects and plants seeking pollination — don’t respond similarly to changing conditions, populations suffer."

DEADLY DEBRIS

UArizona researchers are working to save communities from post-wildfire debris flows, an environmental hazard we're only beginning to understand.

Post-wildfire debris flows are fast-forming slurries of soil, wood and other material, triggered by intense rainfall on sloped landscapes in the wake of a burn. They don't behave like flowing water and have been clocked at over 35 mph — six times the speed of a flash flood — crashing forward with the roar of a freight train.

A recent post-fire debris flow in California killed 23 people and destroyed more than 400 homes. Even when not directly hitting communities, the flows deposit sediment that drastically bulks up later flooding, as happened following the 2010 Schultz Fire near Flagstaff, AZ. One analysis estimated resulting damages at $147 million.

The study of post-wildfire debris-flow hazards is nascent, and while scientists have learned much about the conditions that trigger the flows, the tools for predicting their behavior are still limited. The few models that exist are based on observations from limited areas and don't perform well in places with different geography, vegetation or weather.

"A major push of our research is to augment existing risk assessments with models that better predict when we're going to get post-fire debris flows, how big they'll be and what they're going to impact, including cascading effects and impacts on water resources," researcher Luke McGuire explains.

Debris flows occur across the U.S., but those in the wake of fires present unique challenges stemming from damage to vegetation and soil. And while wildfires were once mainly a seasonal problem in dry climates only, global warming is driving more frequent and intense fires and burns in even historically cooler, wetter regions like the Pacific Northwest.

"Fire regimes are changing," researcher Ann Youberg says. "We can have wildfires at any time of year now, and because of climate change, drought and invasive species, we have ecosystems burning that aren't adapted for fire. As those fires become more common, so do post-wildfire debris flows."

Researchers assess runoff potential in an area burned by the 2021 Telegraph Fire near Globe, AZ.

Luke McGuire is an assistant professor in geosciences with research focused on geomorphology, landslide hazards and numerical modeling.

Ann Youberg is a senior research scientist with UArizona's Arizona Geological Survey. Her research focuses on post-wildfire geomorphic responses and geologic hazards.

PLANNING FOR EXTREME HEAT

Ground-breaking work shows communities are ill prepared for the deadliest weather hazard in the United States.

Ladd Keith's research is helping city and regional planners better understand, prepare for and adapt to increasing heat, the leading weather-related killer in the U.S. Though heat threatens the foundations of civilization — from economic and political stability to food and energy security, only in the last decade have governments begun to seriously grapple with its challenges.

Just a handful of states have laws about working in heat, and the Occupational Safety and Health Administration only recently began to address the issue. Other federal programs, from highway projects to the Department of Housing and Urban Development grants, include far less considerations for heat risk or thermal equity than other hazards, such as flood or fire.

"The nasty truth of it is that heat is invisible," Keith says. "Events like flooding or wildfires create striking images and videos that grab people's attention. Also, the influential real estate development and property insurance industries have been more keyed into those risks."

One more factor: Extreme heat most impacts low-income and marginalized communities. Research has shown a racial legacy of red-lining, practiced by the Federal Housing Administration beginning in the mid-1930s and only formally ended by the Fair Housing Act of 1968.

Today, even middle-income areas that were once segregated trend hotter than income-comparable areas where the residents are primarily white, a phenomenon researchers link to more concrete and dramatically fewer trees in those communities.

Challenges in Assessing Risk

Ladd Keith recently led a team measuring heat exposure at outdoor COVID-19 vaccination sites: a small project, but one that illustrates some of the many challenges in planning for and dealing with urban heat.

For starters, there's granularity. Someone in an asphalt lot experienced different exposure compared to someone in a tent or on grass.

"Heat maps are one of the main tools cities use for assessing risk, but they only give us a big-picture idea of heat," Keith explains. "Heat is vastly different across even a single site or neighborhood, and understanding those nuances is really complex for cities."

New Guidance for Planners

Ladd Keith and co-author Sara Meerow (Arizona State University) recently wrote *Planning for Heat Resilience*, the American Planning Association's first authoritative guidance on extreme heat planning and resilience.

https://bit.ly/3y5N8Ad

Ladd Keith is an assistant professor in the School of Landscape Architecture and Planning with research interests in heat planning, policy and governance.

Keith is UArizona's co-principal investigator in a five-year effort to evaluate public health resources and systems for climate change challenges, funded by the CDC's Building Resilience Against Climate Effects program.

Thermal image of an outdoor COVID-19 vaccination site showing the heat of cars impacting volunteers and medical staff. https://www.sciencedirect.com/science/article/pii/S2667278221000407#fig0004

"Extreme" heat is also relative. Some volunteers who simply weren't acclimated to spending hours outdoors suffered heat exhaustion on a 75°F-day. Similarly, 75°F would feel very different for someone acclimated to Tucson, AZ, versus Juneau, AK.

And what about protections for people required to work outdoors? Where does responsibility for their safety lie? The vaccination sites Keith studied were in the City of Tucson in the State of Arizona, carrying out a federally funded program administered through county-level offices.

Working Toward Change

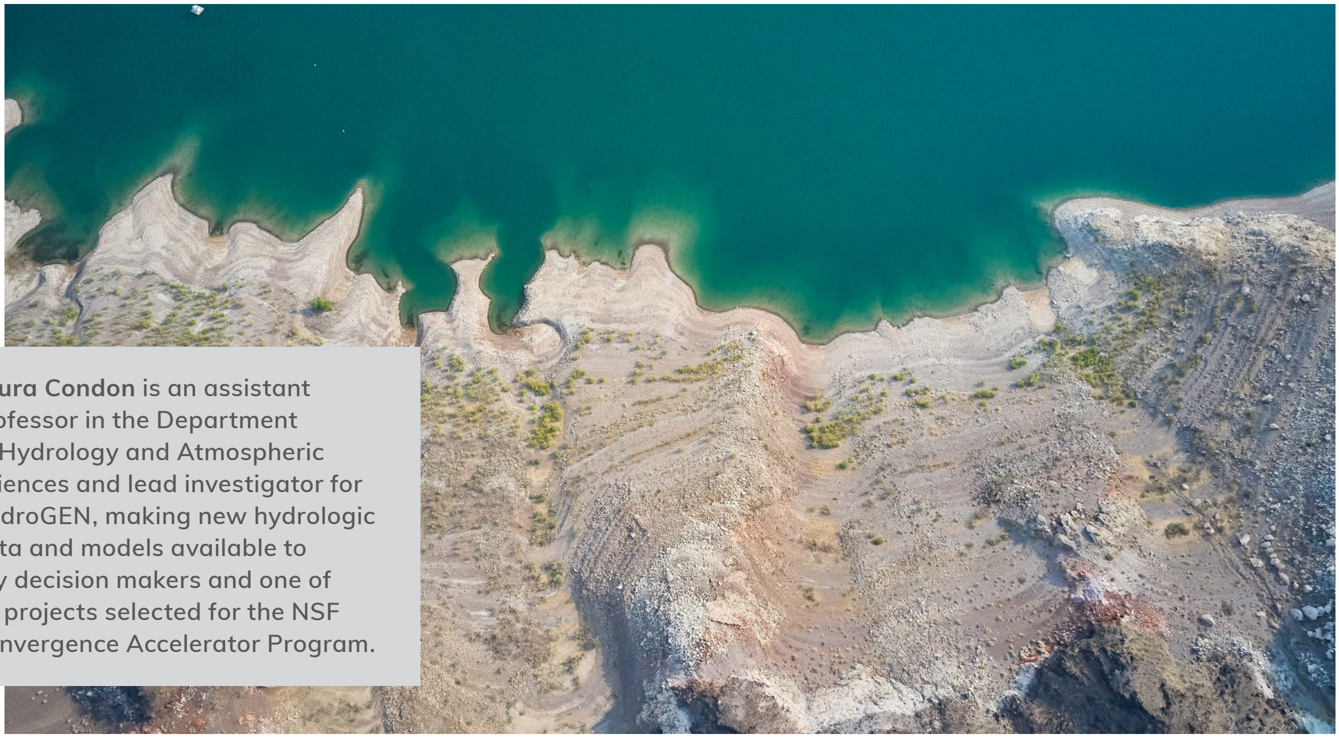
While the challenges around heat abound, Keith is focused on solutions. He recently co-authored the first nationwide survey of planners on heat-related resources available to them, as well as their heat strategies and concerns.

That work led to a NOAA-funded project with major U.S. cities to analyze the extent of their current planning and identify areas of future heat risk.

The project is poised to constructively address the public health risks of heat, as only a fraction of the country's nearly 20,000 communities could today tackle the issue without more state and federal support. Any community can access NASA satellite data for land surface temperatures, but most have no access to experts who can translate that data into meaningful planning — a key pillar of Keith's work.

"Smaller communities and rural communities just don't have the resources for this kind of work," Keith says. "We really need to think through what institutions are needed to support decision making for heat and what roles state and federal governments need to play."

Learn more at UA News
https://bit.ly/3OV4sxO



Laura Condon is an assistant professor in the Department of Hydrology and Atmospheric Sciences and lead investigator for HydroGEN, making new hydrologic data and models available to key decision makers and one of 10 projects selected for the NSF Convergence Accelerator Program.

Photo: Drew Bennett

FIRST-OF-ITS-KIND MODELING SHOWS GROUNDWATER CRISIS IN THE MAKING

The combination of groundwater pumping and global warming is changing landscapes across the U.S.

Work by hydrologist Laura Condon shows that groundwater pumping in tandem with a warming climate will mean dramatic changes to U.S. landscapes, especially in less heat-adapted regions east of the Rocky Mountains. As warming and pumping persist, diminishing groundwater will increasingly threaten vegetation and sever vital connections between rivers, streams and underground reservoirs.

In the first study of its kind at a national scale — one with important implications for managing water resources — Condon and research partners showed that large-scale pumping has already contributed to the loss of 649 million acre-feet of groundwater since the 1950s: enough to put all of Montana, Idaho, Wyoming, Nevada, Utah, Colorado, Arizona, New Mexico and most of California under a foot of water.

A follow-up study, also first-of-its-kind, showed that even a 2.7°F global warming above pre-industrial levels — the target of the Paris Agreement but an increase much lower than some models predict — will cause the U.S. to lose an additional 96.5 million acre-feet of groundwater: roughly one fourth the volume of Lake Erie.

Most national-scale hydrologic models only account for the vertical movement of water, such as rain percolating from vegetation into the soil and roots pulling up water from the ground. In contrast, Condon's modeling innovations simulate the lateral movement of subsurface water and its connections with surface water and land.

Learn more at UA News
https://bit.ly/3tB2Iqm
https://bit.ly/3irPzEa

BRINGING RIVERS BACK TO LIFE

Study shows biodiversity can rebound with high-quality effluent feeding once-dry river systems.

Researcher Michael Bogan found that high-quality effluent (treated sewage) can drive a rapid and robust ecosystem rebound. His work demonstrates that wastewater could play a role in restoring ecological connectivity, especially in arid and semi-arid lands where natural water systems have been depleted.

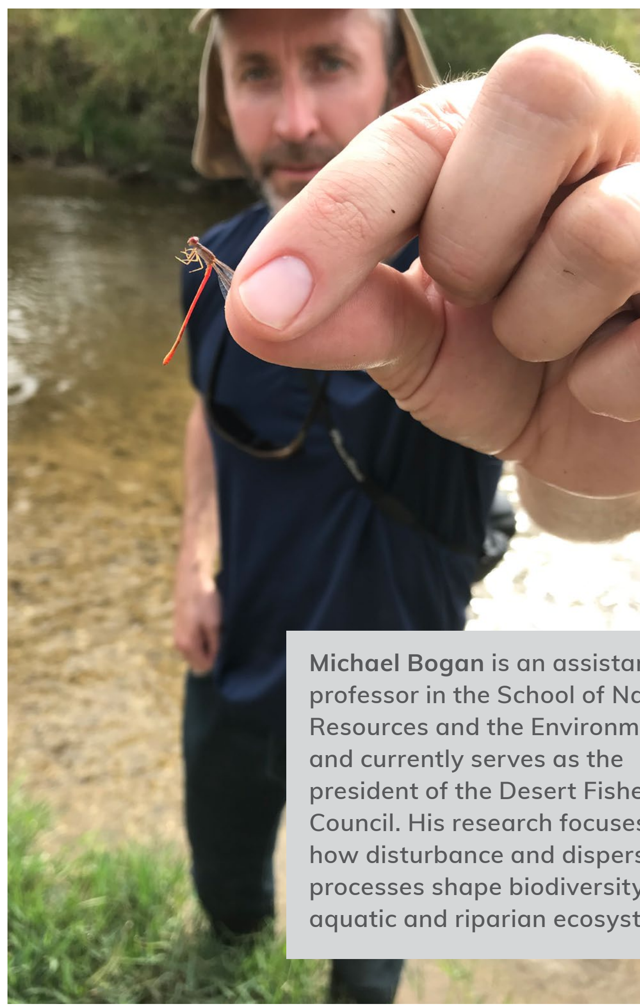
Scientists have long observed that due to trace contaminants and other issues, streams fed by treated sewage support considerably less biodiversity than natural streams. In recent years, however, many water treatment plants have upgraded their technologies in ways that can drive stronger ecosystem recoveries.

Bogan and student researchers made the discovery at the Santa Cruz River, which snakes through Tucson but ran dry decades ago, flowing only with periodic stormwater. When the city began releasing millions of gallons of high-grade reclaimed water into sections of the river, the ecosystem impact was immediate.

"Within the first day, we saw seven different species of dragonflies," Bogan says, singling out a remarkable harbinger of resurgence. While earlier studies of the dry Santa Cruz riverbed had identified only a handful of insect species, Bogan's team found 150+ kinds of aquatic insects along the river within 10 months of its new flow: "What you would see in a site that had been flowing for a very long time," Bogan says.

Learn more at UA News
https://bit.ly/3MOGzqq

Treated effluent in the Santa Cruz. Photo: Michael Bogan



Michael Bogan is an assistant professor in the School of Natural Resources and the Environment and currently serves as the president of the Desert Fishes Council. His research focuses on how disturbance and dispersal processes shape biodiversity in aquatic and riparian ecosystems.

Bogan holds a damselfly. Photo: Claire Zugmeyer, Sonoran Institute.

GROUND-LEVEL SURVIVAL

Researcher Rachel Gallery is helping scientists understand the life-giving, climate-protecting microbiology under our feet.

Rachel Gallery is an associate professor in the School of Natural Resources and the Environment, co-PI of UArizona's NSF-funded Critical Zone Collaborative Network and director of the Gallery Lab. She studies the ecology of soil microbes, plant-microbe interactions and how ecosystems respond to global change.

The nation that destroys its soil destroys itself. For Rachel Gallery, that statement is as true today as when president Franklin Roosevelt penned it in 1937 in the wake of the Dust Bowl disaster.

Gallery's research illuminates the dynamics of soil microbes: their physiologies, their diversity and community compositions, how they break down matter and cycle nutrients and how they respond to fires, drought and other events.

One branch of Gallery's work combines on-the-ground sensing with flyover, hyperspectral imaging. The goal is to develop models that predict microbial compositions and functioning where direct sampling isn't an option.

Other studies incorporate longitudinal data from systems like FLUXNET and the National Ecological Observatory Network, which perform automated, ongoing environmental measurements.

To understand, for example, how wildfire affected soil microbes and their recovery trajectories, Gallery used extant data from UArizona's Critical Zone Collaborative Network to establish baseline conditions predating a burn. The research showed that fires can dramatically alter microbe communities and make those landscapes less effective at carbon sequestration.

Gallery's work aligns with a growing public awareness that soil is a critical carbon sink for slowing global warming and a nonrenewable resource. It takes microbes millennia to break down bedrock into topsoil, which might then be burned, polluted or otherwise decimated in moments.

BRIDGES to Cross-Discipline Careers

Gallery is co-PI for UArizona's NSF-funded BRIDGES program — Building Resources for InterDisciplinary Training in Genomic and Ecosystem Sciences. This workforce-development initiative includes mentorship and professional training to prepare graduate students for careers in fields ranging from food security to medical genetics.

SHRINKING CARBON "DISCOUNTS" IN ARID LANDS

With FLUXNET data from the Sonoran Desert, researcher David Moore has found one more way in which heat is a self-compounding problem.

David Moore is a professor in the School of Natural Resources and the Environment. Since 2008, Moore has led/co-led the NSF- and DOE-supported Fluxcourse for international researchers, training scientists how to measure carbon, moisture and energy fluxes to quantify the relationship between ecosystems and climate.

Researcher David Moore has an interesting way of framing the terrestrial carbon cycle, in which plants move CO_2 from the air to soil, where microbes continually release some of it back. "Today, plants basically give us a 50% discount on the carbon dioxide that we emit," he says.

With vegetation key to that exchange, you might think deserts have little impact on global carbon levels, but recent research shows arid lands are tied to yearly CO_2 fluctuations. Moore has figured out why, revealing yet another "snowball" effect of global warming.

When it's hot, plants close their pores to conserve moisture, also shutting down their absorption of CO_2. However, that same heat does not shut down soil microbes. They go on releasing CO_2 undeterred, resulting in more airborne carbon.

Moore found that this disruption is common, even in arid lands, where plants are better adapted for heat. And while the fluctuations go both directions, effectively canceling to zero over long periods of time, Moore's modeling neatly accounts for the otherwise mysterious annual variations.

The research is vital for predicting how heat can impact food production, especially in arid lands where crops are more at risk. Moore and the student and postdoc collaborators he mentors, do much of their work in collaboration with Russ Scott of the U.S. Department of Agriculture.

"I really want to know how things work," Moore says, "but I also want to do something useful. With this data, we're discovering a lot more about how ecosystems respond in real time to variations in moisture and temperature and to really understand how these systems work."

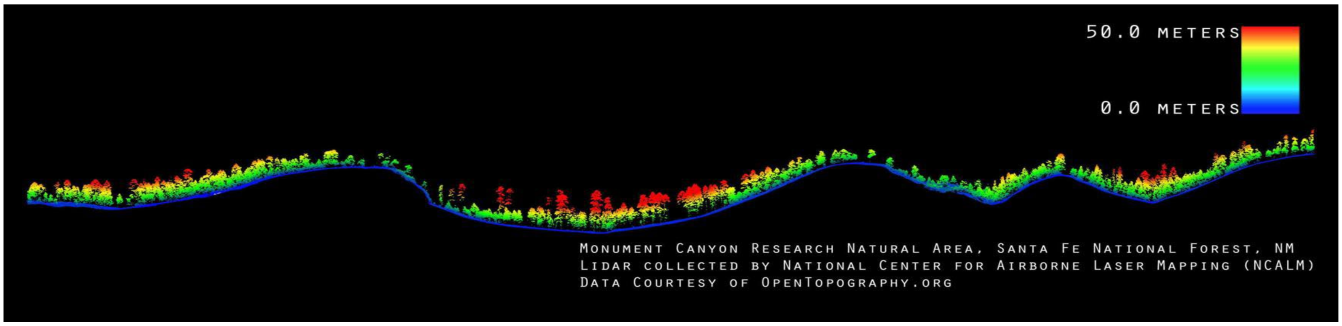
High-Resolution Data

Much of Moore's work uses data from FLUXNET, an ever-growing, grassroots, global network of sensing towers that measure ground-to-air exchanges of water vapor, carbon and energy.

Some towers provide multiple readings every second, with data going back years and even decades — very different from other sources of terrestrial data, such as images from satellites that provide whole-Earth imaging but fly over any given area only once every 16 days.

DEMOCRATIZING CLOUD COMPUTING

The UArizona-led CyVerse accelerates breakthrough science by making NASA-level computing freely available to anyone with an internet connection.



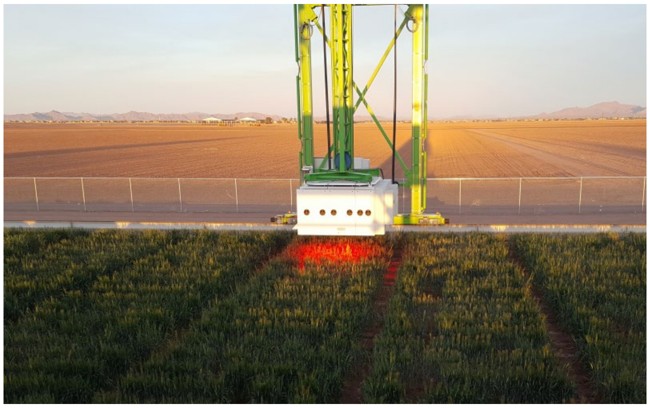
Tyson Swetnam first encountered CyVerse years back as a postdoc with a problem. He was analyzing energy inputs and outputs across a large swath of land in the Santa Rita Mountains. He had terabytes of data. He had complex models to transform that data into knowledge. What he didn't have were the hundreds of thousands of hours he'd need to run the numbers, even on high-end computers.

Eric Lyons had the solution. Actually, students in the CyVerse class that Lyons teaches developed a solution. They transformed the problem into multiple workflows that ran over a network of supercomputers and computer clusters distributed around the world, then reassembled everything into meaningful charts, graphs and tables, all through the CyVerse platform.

CyVerse is an expandable, problem-solving ecosystem that combines cloud-based data storage, high-performance distributed computing, analytics software, data visualization tools and more. Start to finish, the project and platform is committed to open-source, collaborative science.

Those who use it — more than 100,000 researchers in 160+ countries and counting — share not just their data, but all of their models, software, code and methodology such that anyone can exactly reproduce their work. They can also build on it, for example by applying uploaded models to new data sets or adapting a block of code to an entirely new function. And all of those newly added resources become potential tools for other scientists.

The CyVerse architecture was designed to process otherwise crippling amounts of data and mind-boggling gigahertz of processing with streamlined efficiency, allowing anyone with an internet connection to use the same tools and resources used by iconic enterprises such as NASA's Event Horizon Telescope explorations.



CyVerse is helping to process data from the world's largest field scanner, mounted on a 30-ton gantry at the Maricopa Agricultural Center. UA News

"The people who join have this vision about dedicating their professional work to enabling others to go further with their science and their education," Lyons says. "Tyson is of that mindset. I'm of that mindset. People who work on this project really are there to create a future where science, research, discovery, teaching and training have no boundaries based on computation."

Learn more at UA News
https://bit.ly/37uR4Q6
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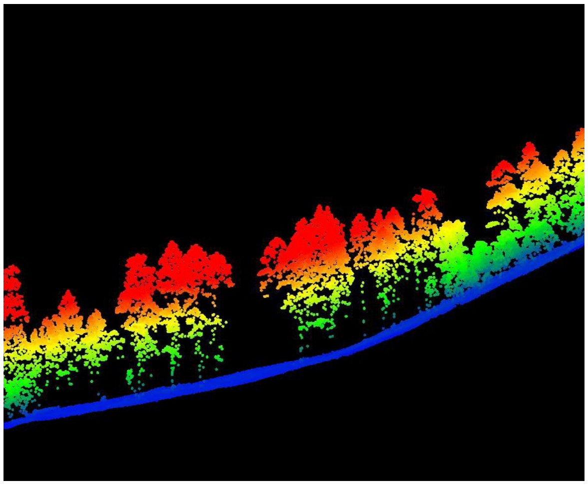


Quantifying Biodiversity Loss

Researchers used CyVerse and records of more than 14,500 plant and vertebrate species to create biodiversity maps of the Amazon. Overlaying the maps with data on fires and deforestation, they found that since 2001, these destructive events have affected 95% of all Amazonian species and as much as 85% of the regional species listed as threatened.

Revolutionizing Agriculture

Imagine robots that move through soil to monitor plant roots and drones flying over fields to create hyperspectral images from across the entire electromagnetic spectrum. Such is the vision for CROPPS, a CyVerse-powered digital biology initiative to record and control plant responses to their environment, producing and sharing massive amounts of data for open-science collaboration.

Eric Lyons and Tyson Swetnam are co-principal investigators of the CyVerse initiative.

Lyons is an associate professor in the School of Plant Sciences with research interests in bioinformatics and genomics as well as scalable computational systems and infrastructure to support and accelerate life science research.

Swetnam is a research assistant professor of geoinformatics at the BIO5 Institute focusing on the applied use of cyberinfrastructure for spatial analysis in the earth and life sciences.

Institute for the Future of Data and Computing

Big Challenges & Big Opportunities in Big Data

The recently established Institute for the Future of Data and Computing (IFDC) advances next-generation data, networking and computing platforms under the leadership of Arthur “Barney” Maccabe, a professor in the School of Information.

Distinguishing the IFDC are its commitments to workforce development and "the ethical and social aspects" of Big Data:

We live in a world where data for and about people is being collected continuously. And, subsequently, the scale of infrastructure needed to preserve and make sense of data is so much more massive than it has ever been,” says Maccabe, former director of the computer science and mathematics division at Oak Ridge National Laboratory. “That’s a big, societal challenge to solve.

IFDC's early initiatives include seeding research that enhances corporate relationships and creating internships and hands-on research experiences for students.

UNLOCKING HALF A CENTURY OF ENVIRONMENTAL KNOWLEDGE

UArizona scientists and students are making 50+ years of NEPA data available to scientists for the first time.

Laura López-Hoffman

The NEPAccess project is ushering in a new era for the 1970 National Environmental Protection Act (NEPA). The brainchild of professor Laura López-Hoffman and UArizona law school dean Marc Miller, NEPAccess is extracting information buried in half a century of documents, giving researchers unprecedented ways to use and analyze that data.

At the heart of NEPA are environmental impact statements (EISs), required for federally-funded projects that might impact local ecosystems. To this day, EIS data is archived primarily in text documents, and no government agency — not even the White House Council on Environmental Quality (CEQ), which oversees NEPA — has ever systematically captured metadata about the assessments.

Much of the initial work to develop NEPAccess is being done by students, including undergraduate Carly Winnebald, who tracks down EISs and manually pulls content to train machine-learning algorithms. In time, automated natural language processing will take over knowledge extraction — ideally for the full 37,000 EISs conducted to date. Winnebald's work has already introduced her to Thomas Sharp, CEQ’s deputy director for NEPA and a UArizona alumnus. It's also enabling research that would have been all but impossible without the newly processed documents. In a first-of-its-kind study, Winnebald and others are currently looking at five years of EISs to analyze and identify patterns among any included environmental justice reviews.

Laura López-Hoffman is a professor in the School of Natural Resources and the Environment and research professor at the Udall Center for Studies in Public Policy. Working at the intersection of environment and human society, her work advances the development of policies and institutions that contribute to human well-being while also protecting ecosystems.

Carly Winnebald is an undergraduate majoring in natural resources with an emphasis in conservation biology.

"NEPAccess defines what it means for a project to be multidisciplinary, combining environmental science, social science, data science, legal science (OK – law!) and user experience tools to provide new pathways for important decisions impacting the environment." - **Marc Miller** is the Ralph W. Bilby Professor of Law and dean at the James E. Rogers College of Law.

FORGING PROGRESS FOR INDIGENOUS DATA SOVEREIGNTY

More than a thought leader, researcher Stephanie Russo Carroll is creating new tools for stewarding Indigenous Peoples' data.

Stephanie Russo Carroll is an assistant professor in public health policy and management and associate director at the UArizona Native Nations Institute. She is a founding member and current chair of the Global Indigenous Data Alliance and co-founder of the U.S. Indigenous Data Sovereignty Network and the International Indigenous Data Sovereignty Interest Group at the Research Data Alliance.

Data about Indigenous people, resources and environments largely continues to be collected, used and controlled by people outside those communities, with little regard for Indigenous rights or interests.

Stephanie Russo Carroll is working to change that.

Carroll co-led development of the CARE Principles for Indigenous Data Governance. She advocates for institutional guidelines to indicate Indigenous data and for enriched metadata that let Indigenous communities specify how their data can be used and who to contact for inquiries.

The work is an uphill climb, for many reasons. Extant repositories often lack good data provenance and weren't designed to adapt for new metadata or governance rules. Compounding the challenges, research enterprises are often loose affiliations, lacking a central authority to enforce change.

Still, Carroll has seen progress and notes that environmental researchers have been some of the earliest to embrace innovation.

The Open TEK (Traditional Ecological Knowledge) database, for example, established a living Indigenous data sovereignty policy, and Earth Science Information Partners are drafting guidelines to implement CARE principles.

Arizona researchers have also been in the vanguard for change. The Arizona Board of Regents has a Tribal Consultation Policy. The UArizona ReDATA repository requires tribal permissions for Indigenous data and is exploring how to accommodate new metadata on provenance and stewardship. The university also requires training for researchers working with Indigenous individuals' data and is currently funding Carroll's work to audit its systems relevant to Indigenous data governance.

Ultimately, Carroll's aim goes beyond good ideas to "the actual operationalization of those principles," she says. "The goal is to create law, policy, ethics and infrastructure that support Indigenous rights to Indigenous data throughout the data life cycle and across data ecosystems."

TERRAFORMING ACROSS THE ATLANTIC

Scientists partnered through the France-Arizona Institute for Grand Global Challenges are learning how climate change could alter Earth's landscapes.

University of Arizona Biosphere 2, Landscape Evolution Observatory (LEO)

April 2022 marked one year of formal operations for the France-Arizona Institute for Grand Global Challenges (FA), an expansive research partnership between the University of Arizona and France's National Center for Scientific Research (CNRS), the largest fundamental research organization in Europe.

Within a year, the institute funded and launched 11 projects, including research into terraforming — the natural processes by which lifeless bedrock becomes soil that can sustain bacteria, fungi, insects, plants and other life. The study illustrates how the institute's complementary resources push the envelope of what science can achieve, spanning investigations at three sites and different scales.

Site 1: In situ observations at sites in the Critical Zone Observatory in Arizona's Santa Catalina Mountains and Jemez River Basin. Here, scientists can monitor landscape and vegetation changes, temperature, precipitation, carbon exchanges and more in real-world, Earth-scale settings.

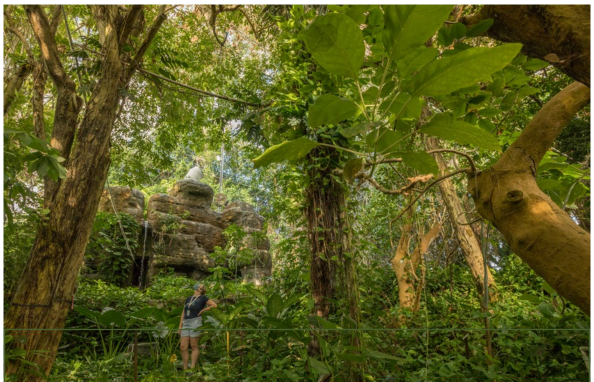
Site 2: Biosphere 2's Landscape Evolution Observatory (LEO), which comprises research sites atop 3,500-square-foot sloped, steel platforms. In an enclosed, controlled setting, scientists can effect large-scale manipulations of air temperature and rainfall to see how more than a million pounds of crushed basalt evolves from pure mineral to life-sustaining soil.

Site 3: Ecotron facility in Saint-Pierre-lès-Nemours near Paris, France. CNRS researchers are working with batches of that same crushed basalt using multiple environmental simulators, each roughly the size of a small toolshed. Here, investigators can conduct far more manipulations and at a smaller scale, varying factors such as atmospheric CO_2 level, humidity, ambient and soil temperatures, light wavelengths, introduced microbes and plants.

Learn more at UA News
https://bit.ly/37uMuRS

TENACIOUS TREES, RESILIENT REEFS

As the world's largest earth science laboratory, Biosphere 2 provides unique environments for climate-change studies and solutions.



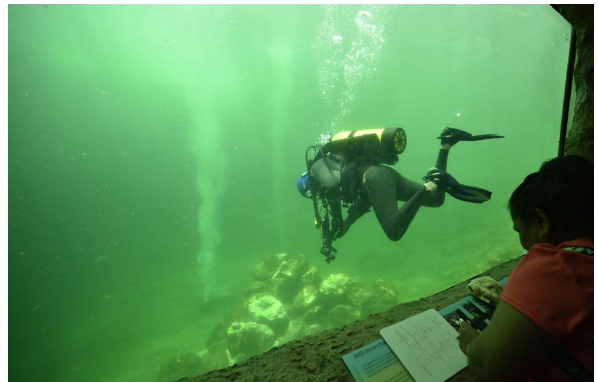
Tropical forests may respond better to global warming than previously believed — an understanding that helps scientists better predict and prepare for future climate.

The finding stems from an unprecedented experiment at the one place on earth it could be done: Biosphere 2’s 30-year-old rainforest, roughly one-fourth the size of a football field and home to 90 plant species.

An international team of 80 scientists created a drought in the forest, gathered data at 400+ sensing points for two months, then returned the forest to normal conditions, starting with a 12,000-gallon "rain."

Researchers are still mining the resulting three terabytes of data but have already found that biodiversity was key to survival: drought-tolerant species enabled the forest to endure, while drought-sensitive species helped it bounce back quickly once water returned.

The forest also responded in ways that supported collective health, including preserving canopies that shaded lower-growing species and increasing the release of compounds that support cloud condensation.



Researchers at Bisophere 2's 700,000-gallon ocean — enough water to fill more than 17,000 bathtubs or a tank 60 feet in diameter and three stories tall — are pioneering ways to make coral reefs more resilient, slowing or possibly reversing the population declines of these critical species.

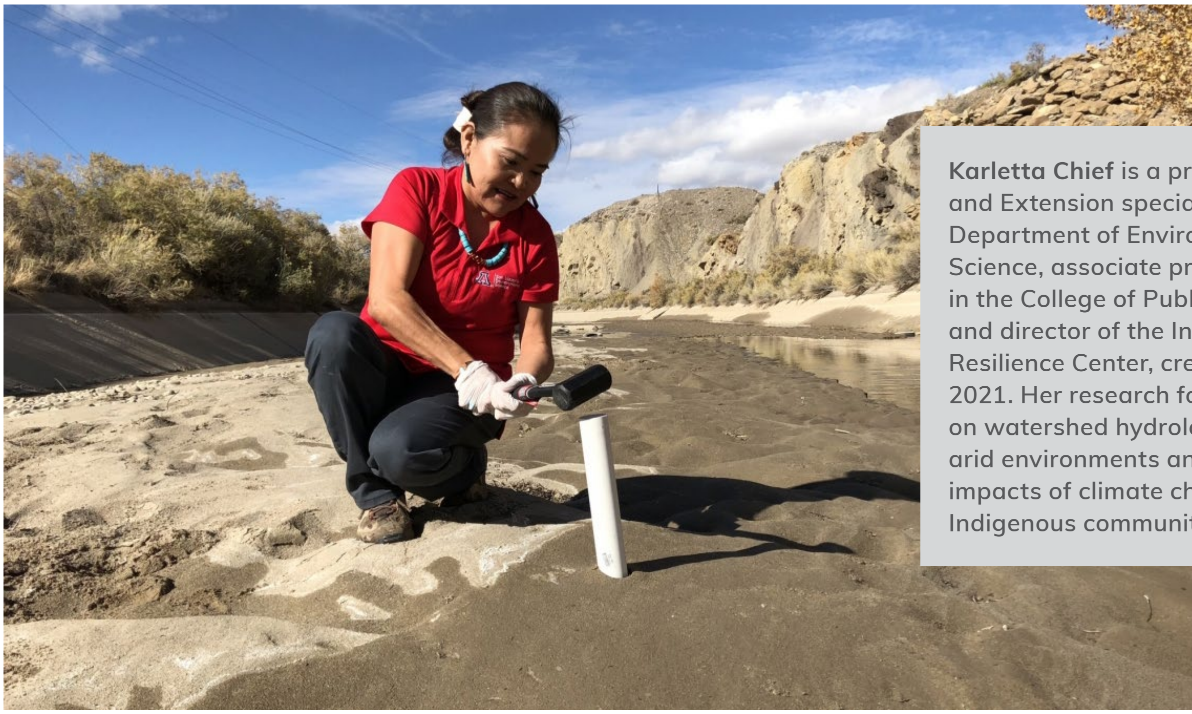
Coral reefs cover just 0.2% of the seafloor but support a fourth of all marine life. They're key to $2.7 trillion in annual economic activity. And they're being destroyed at alarming rates as oceans absorb excess heat and carbon.

A recent analysis from NOAA found that 14% of the world’s coral reefs have been destroyed in roughly the past decade alone. Heat and acidity also slow coral growth by up to 40%.

Experiments at Biosphere 2 are testing solutions for building resilient reefs that can withstand the oceanic heat and acidity conditions scientists project will be widespread by 2050. Researchers are also cultivating microorganisms that live within coral colonies to make them less vulnerable to environmental stress.

SCHOLARSHIP, OUTREACH AND TRUST

At the heart of the newly created Indigenous Resilience Center are research and projects that not only benefit Native Nations but are driven by tribal priorities.



Karletta Chief is a professor and Extension specialist in the Department of Environmental Science, associate professor in the College of Public Health and director of the Indigenous Resilience Center, created in 2021. Her research focuses on watershed hydrology in arid environments and the impacts of climate change on Indigenous communities.

Photo courtesy of Karletta Chief

The University of Arizona has launched the interdisciplinary Indigenous Resilience Center (IRC), which works on projects and partnerships with Native American nations to advance tribal communities' efforts to respond to environmental challenges.

"The university has many programs and centers that focus on Native Nations, and the environment is so important to Native Nations," says IRC director Karletta Chief. "Many tribes have a deep connection to the land through their livelihoods, cultures, traditions and even their religion. So there was a clear need to do this type of partnership and outreach to support the environmental resilience of tribes and bring all of these different efforts together."

In part, the IRC became the vehicle to continue the work of the NSF-funded Indige-FEWSS program (Indigenous Food, Energy and Water Security and Sovereignty) which combines research internships, teaching and cultural immersions for students.

The IRC will sustain a PhD minor in food, energy and water systems and a campus-wide Native Voices in STEM seminar series that was created by Indige-FEWSS. The IRC is also recruiting new faculty who have expertise in working with Native Nations on environmental challenges. Planning for new initiatives, including defining what "resilience" means for Indigenous communities, is happening in consultation with tribes so that the center's activities are driven by their priorities.

"There's a lot of work to be done with Native Nations," Chief says. "I feel this center marks a turning point and reflects a true commitment by the University of Arizona in going beyond the land acknowledgement and honoring the first people here in the United States."

Learn more at UA News
https://bit.ly/37xIksi
https://bit.ly/3kZobi3

A hoop house with tomatoes and peppers grown in New Mexico.
USDA Photo by Bob Nichols

Diné College student and Indige-FEWSS participant Larry Moore demonstrates use of a solar-powered water filtration system to community members on the Navajo Nation.

Indige-FEWSS in Action

Hoop House Overhauls

UArizona students recently teamed up with students, faculty and specialists from Diné College to create an innovative greenhouse design. Their work is part of an effort to create greater food security and food sovereignty for the Navajo Nation, which has less than 15 full-service grocery stores across its 27,000 square miles.

Beginning with a conventional hoop house design that offers only modest protection from the elements, the teams' innovations included a solar-paneled cooling system and propane heating, making the solution viable for year-round food production even among the reservation's many households with little or no electricity.

Because soil in many areas of the Navajo Nation is contaminated or otherwise unsuited for agriculture, the initial design also experiments with alternative media for growing food: hydroponics, coconut husks and a porous volcanic material.

Tó éí iiná át'e / Water is Life

With no large-scale public water systems, many families on the Navajo Nation regularly drive long distances to haul water for drinking, cooking and bathing. Often they rely on unregulated sources that have hazardous levels of contaminants from mining activities.

In 2019, UArizona graduate students worked with undergraduates on the Navajo Nation to design a solar-powered water filtration system. Made mainly of materials available at ordinary hardware stores, their design can provide 50 gallons of safe, clean water daily to 30 Navajo households.

In 2020, facing a pandemic that shut down access to bottled water in stores and isolated many Navajo families in their homes, UArizona students returned to work with the Navajo Nation Water Access Coordination Group. Together, they designed new systems at a household scale and trained local technicians to build them.

A SMARTER TAKE ON STORMWATER

UArizona is helping Tucson become a model for harvesting rain and runoff to create greener, healthier communities in arid lands.

With Arizona weathering its worst drought in 1,200 years, researcher Andrea Gerlak is helping Tucson become a model for stormwater management. Whereas many U.S. municipalities focus on keeping rain from overwhelming sewer systems and isolating runoff due to picked-up contaminants, Tucson's "One Water" approach sees stormwater as an invaluable resource for improving the city.

As a subset of the larger green infrastructure (GI) movement, green stormwater infrastructure diverts rainfall from impermeable pavement and parking lots to create green streets, shaded swales and other projects that reduce ambient heat, capture carbon, improve air quality, prevent flooding, lower energy needs and even improve residents' mental and physical health.

"These strategies were part of everyday life for the Indigenous tribes of this region," Gerlak says, tracing back thousands of years to practices of the Hohokam people. Tucson has been reviving GI over the past two decades, and Gerlak believes universities have an important role to play in coalitions taking on that work.

Increasingly, one of the biggest challenges to GI has been maintenance, with neighborhoods and government employees ill prepared to take care of projects beyond implementation. UArizona recently led a collaborative, participatory process to help develop a maintenance protocol for Tucson, researching best practices and creating capacity-building trainings through UArizona Cooperative Extension.

The university is also designing monitoring programs that combine maintenance with longitudinal research, including public science data collection. Some elements have been wrapped into UArizona courses to ensure continuity and provide experiential learning, for example having students assess infiltration and other hydrologic properties at GI sites.

UArizona can also help address persistent inequities, Gerlak says. Research has shown that simply providing equal access to GI incentive programs and equally distributing improvement funds nonetheless mainly improved wealthier communities, which had already enjoyed greener neighborhoods and less flooding.

"We're at a place now where we need to focus on the performance of GI to learn what really works," Gerlak says. "At the project level, in terms of design and hydrology and connectivity, but also in terms of inclusion, social justice and getting our investments to perform better for all residents. That's where partnerships between the university, government, communities and NGOs are most valuable."

Andrea Gerlak is director of the Udall Center for Studies in Public Policy and a professor in the School of Geography, Development and Environment, studying the interface between science and policy and issues of environmental equity and justice.

As a senior research fellow with the Earth System Governance Project, Gerlak works with a coalition of nearly 3,000 scholars around the world to find political solutions and novel governance mechanisms to address global environmental challenges.

"SLOW AGRICULTURE" OFFERS A TRIPLE WIN IN ARID LANDS

A modern take on native plants can increase food security, reduce resource consumption and improve public health.

Erin Riordan is a research associate at the Desert Laboratory on Tumamoc Hill in Tucson and conservation research scientist at the Arizona-Sonora Desert Museum. Riordan coordinates the Desert Lab's binational research on indigenous crops and agriculture strategies, work co-led by research social scientist Gary Nabhan.

White tepary pods and beans. Photo: Dena E. Cowan

Applied ecologist Erin Riordan is at the forefront of a movement reinventing agriculture in arid lands to improve food security, public health and resource stewardship. One solution: marry contemporary technologies with indigenous plants and traditional intercropping tactics.

"Desert plants have evolved a remarkable number of strategies to cope with heat, drought, unpredictable rainfall and poor soils," Riordan says, contrasting them with vulnerable, resource-intensive conventional crops.

Leading a team of international researchers, Riordan studies edible plants naturally adapted to extreme weather, such as cacti, succulents and nitrogen-fixing legume trees. She recently helped identify 17 categories of such plants native to Northern Mexico and the southwestern U.S. — foods that also promote healthier blood sugar levels and provide diverse antioxidants.

These no-till crops can be co-located with rainwater harvesting and renewable energy. Low-growing foods can be sown under solar panels for partial shade and soil moisture retention, for example, or intercropped among native trees that offer those benefits plus more resilient soil microbe proliferation.

Researchers note that some such crops may take five to 12 years to produce initial nutritional harvests, earning them the moniker of "slow agriculture." However, thereafter they produce more edible biomass compared to conventional crops, and at a fraction of the water and energy input.

Learn more at UA News
https://bit.ly/3w24Q4X

Community Scientists Explore Environmental Contamination

Through the NSF-funded Project Harvest, environmental science associate professor **Mónica Ramírez-Andreotta** worked with university and community partners to engage some 150 people to harvest and test rainwater samples in communities impacted by environmental contamination.

Increasing diversity and inclusion were key goals of the project, since marginalized communities are often most at risk from environmental hazards. Nearly half of the participants were people of color, people from low-income households and people without a four-year college degree.

Findings from the study will be published beginning in summer 2022.

SCIENCE AT THE NEXUS OF WATER, ENERGY AND FOOD

Southern Arizona's desert heat provides an ideal testing ground for technologies that will build resilience around the world.

Photo courtesy of Greg Barron-Gafford

Greg Barron-Gafford, professor in the School of Geography, Development and Environment, is part of a team of scientists showing how agrivoltaics — growing crops beneath solar photovoltaic panels — can revolutionize food, energy and water security in arid lands.

In experiments contrasting agrivoltaic and traditional agriculture, researchers found that some crops produced up to triple the output of traditional agriculture when cultivated under the shade of solar panels.

That shade also meant a single irrigation could support growth for days, compared to just hours in the traditionally planted crops. And because plants release moisture, they also cooled the solar panels above them, increasing the panels' production efficiency.

Beyond this win-win-win, agrivoltaics could also improve the well-being of laborers. Preliminary data showed workers' skin temperatures were as much as 18°F cooler when tending the agrivoltaic crops.

Guayule. U.S. Department of Agriculture

As head of the Sustainable Bioeconomy for Arid Regions Center, Kimberly Ogden oversees research into heat — and drought — resistant plants that can be used as feedstock for fuel, rubber and other high — value products.

The shrub guayule, for example, produces natural rubber and organic resins and requires 30 to 40% less water than other desert plants. About 85% of its biomass can be converted to biodiesel, jet fuel and kerosene.

An engineering professor and chair of the Department of Chemical and Environmental Engineering, Ogden focuses much of her own research on bioreactor design, including algae, which grow naturally in saltwater, freshwater and wastewater. Most feed on sunlight and convert CO_2 into useful products.

Up to half of algal biomass can be converted to fuel, and what remains has applications ranging from eco-plastics to nutrition, being high in both protein and carbohydrates.

Closing Thoughts

GREG COLLINS ON BUILDING RESILIENCE

Over the past two years, the far-reaching effects of the pandemic compounded existing challenges to pull some 56 million already poor people into crisis-level poverty and hunger.

Greg Collins, research professor and associate vice president of resilience and international development, believes expertise across the University of Arizona can help vulnerable communities around the world better weather both recurrent and unanticipated threats.

Q: When we talk about "resilience" in international development, what do we mean?

We're really talking about the ability of people to maintain well-being in the face of shocks and stresses — to mitigate, adapt to and recover from those stresses. I have a colleague at Cornell who describes resilience as "shock-proofing continuous improvement in the human condition."

Q: Are these naturally occurring stresses or something more complex?

Today we're facing what I call the "triple threat" of conflict, COVID-19 and the accelerating impacts of climate change. If you look at a place like the Horn of Africa, where I spent nearly half my career in international development, on top of coronavirus and climate, they're dealing with locusts, herder-farmer conflicts over resources, conflict spilling over from Somalia... These are very complex, compound-risk environments.

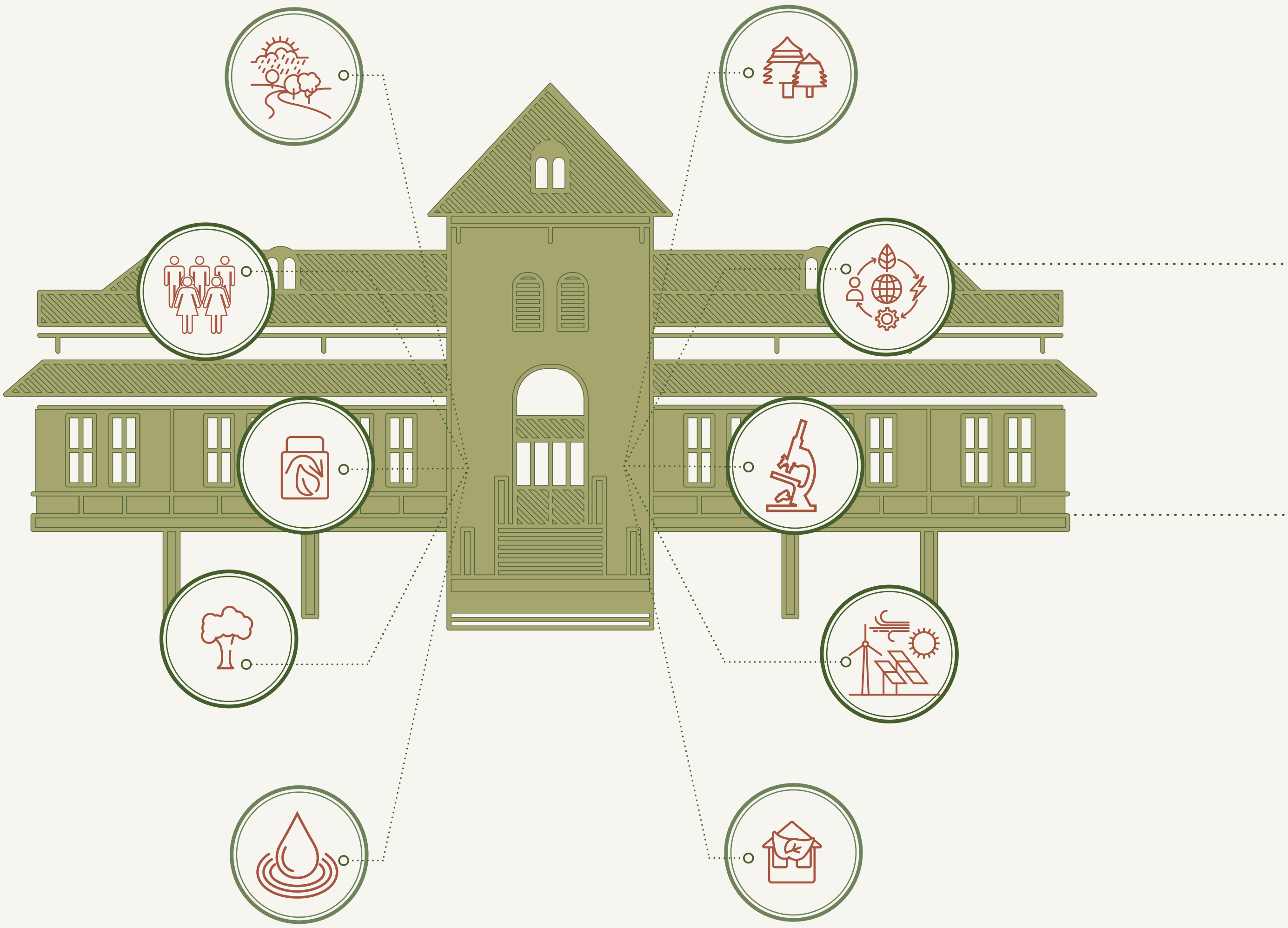
Q: How do you see the University of Arizona positioned to help?

The roots of resilience work in international development are actually in the drylands of Africa, and so much of the resilience-relevant research being done here is tied in one way or another to the fact that we live in the arid lands of the Sonoran Desert.

We deal with recurrent droughts and sustained droughts. We deal with extreme heat. We're already finding solutions to those challenges. That creates an incredible opportunity to mobilize multidisciplinary science teams to then adapt and translate those solutions to tackle these urgent challenges and support other communities and countries in their work to strengthen their own resilience.

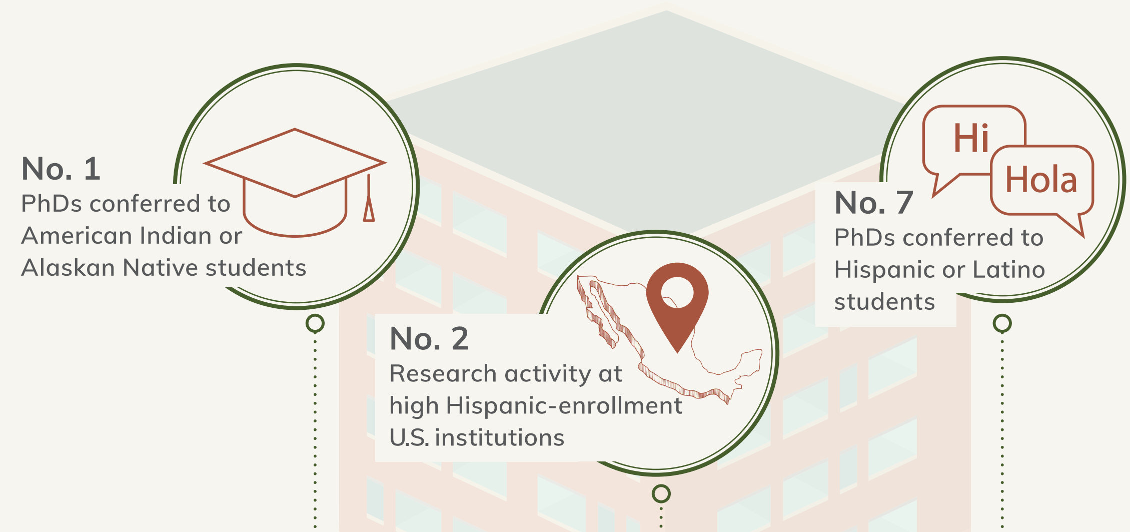
Research and Scholarship

BY THE NUMBERS



THE UNIVERSITY OF ARIZONA: TOP 4% IN R&D

At **$761 million**, the University of Arizona ranks among the **top 20 U.S. public universities** in research and development expenditures and **35th** among U.S. universities overall.

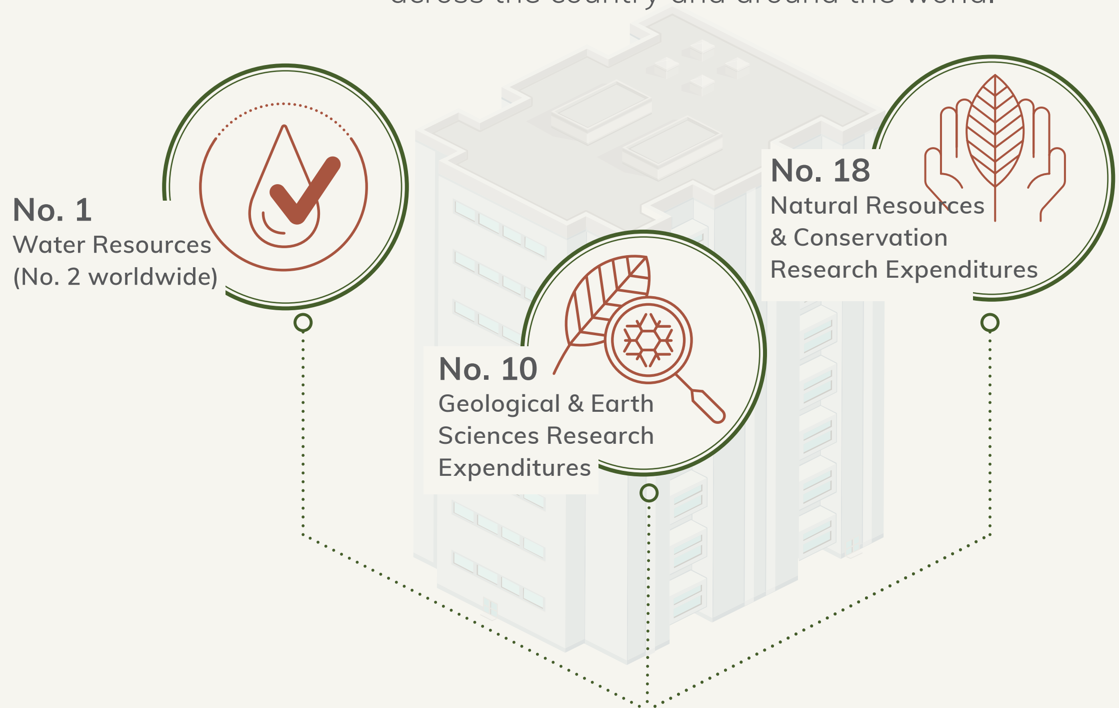


ADVANCING DIVERSITY

UArizona is working to better serve and connect with populations under-represented in higher education.

LEADING SCIENCE AND SCHOLARSHIP

UArizona scholars are pioneering work in environmental and ecological research in Arizona, across the country and around the world.



Established in 1885, the University of Arizona is the state's land-grant university. Ranked 16th for the employability of its graduates, UArizona is also a leader in research, bringing in more than $761 million in research investment in FY20. As a member of the Association of American Universities, the 62 leading U.S. public and private research universities, UArizona is advancing the frontiers of interdisciplinary scholarship and entrepreneurial partnerships.

FOCUS ON ENVIRONMENT & ECOLOGY

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