



# ANNUAL REPORT


2021 - 2022

# Finding Common Ground

The Inflation Reduction Act of 2022, with its incentives for renewable energy, required no small amount of compromise. More will be needed to help companies and communities find common ground when it comes to building new solar farms. The choice of locations can often be contentious, notes Woods Senior Research Scholar Dan Reicher, who this year worked with our Policy and Engagement team to launch a new series of [Uncommon Dialogues](#) building consensus on where to site solar farms.

In August, Reicher told the [Los Angeles Times](#) about convening “more than 20 groups —representing the solar industry, environmental advocates, Native American tribes, the agriculture industry and local governments—in an ‘Uncommon Dialogue’ to discuss land-use conflicts involving large solar farms.” This convening follows the success of Reicher’s last Uncommon Dialogue series that reconciled the interests of the hydropower industry and conservation groups with an [agreement](#) to rehabilitate (for safety), retrofit (for power) or remove (for conservation) dams on the nation’s rivers.

The solar dialogues are designed to help companies work with local community members and conservation practitioners with insights on where to locate projects. “Done well, siting is a highly technical process that also lends itself to significant input,” Reicher said.



**On the Cover:** Earth’s forests are unique in that they can exacerbate global warming, or serve as a key solution for climate mitigation. Strategies for enhancing the ability of forests and other natural carbon sinks to absorb and store greenhouse gasses are known as natural climate solutions. Woods scholars are helping develop a new initiative exploring the potential for such solutions thanks to a generous new gift to the Stanford Doerr School of Sustainability (see page 4). Credit: iStock/[GettyTim82](#)

# A Word from Chris Field



Welcome to the first annual report produced from the Woods Institute's new academic home within the Stanford Doerr School of Sustainability.

The launch of the new school is a truly uplifting and encouraging moment. It's a tremendous validation to see the university and its supporters make such a significant investment in research and education focused on the environment, climate and sustainability.

The excitement of those joining us on this new path is palpable. It's humbling and inspiring to know we can help support this critical next step toward Stanford's long range goals to accelerate its purposeful impact in the world.

Much of the past year has been spent preparing for this transition, and I deeply appreciate all the efforts faculty, staff and our volunteers have made to get us to this point. Their efforts have paved the way for the launch of a new Sustainability Accelerator, coalesced the vision of a new initiative on Natural Climate Solutions, and launched the Healthy Planet, Healthy People Initiative with funding, courses and new Planetary Health fellows that perfectly illustrate the energy and commitment of all those who are bringing SDSS to life.

Between the new school's opening and the recent passage of transformative U.S. infrastructure and climate legislation, our sense of collective optimism is higher than it's been in recent memory. It couldn't come at a better time. Climate-fueled extremes continue to break records, and the need for solutions is greater than ever. I hope reading about some of the advances our community has made over the past year provides further hope we can create a future where humans and nature thrive in concert and in perpetuity.

Regards,

Chris Field

Perry L. McCarty Director



challenges. It is exciting to tackle those challenges with expanded ambition, new resources, and a motivated, capable team.”

In addition to a new structure, SDSS will bring new multidisciplinary initiatives to the institute, all designed to bring Stanford scholars together in new ways to collaborate on solutions-oriented research. At various stages of development, these initiatives will encompass existing centers and programs while opening up new lines of research, funding, and opportunities for faculty scholarship to have an impact in the world. Housed within institutes with a track record of empowering collaboration and fostering external partnerships, these initiatives provide an open door to faculty and students who want to engage in climate and sustainability scholarship, whether or not they belong to departments or degree programs in the new school. Read more about two new Woods Institute-based initiatives already underway or in development.

### HEALTHY PLANET, HEALTHY PEOPLE

Current models of industrialization and consumption are eroding biodiversity, degrading the environment, and impacting the ability of ecosystems to support human communities.

Climate change and other environmental challenges are creating a health crisis of planetary dimension, with impacts falling disproportionately on vulnerable and historically marginalized populations.

Comprehensively understanding the linkages between the environment and human health allows us to design policies and systems that account for the true costs of environmental degradation and conservation.

Over 130 scholars are collaborating through the new Healthy Planet, Healthy People (HPPH) Initiative to expand the field of human and planetary health scholarship, bringing together perspectives from environmental sciences, public health, systems thinking, and other disciplines to achieve breakthroughs and find solutions.

### New Initiatives In Development

- ▷ Freshwater Solutions
- ▷ Healthy Planet, Healthy People
- ▷ Natural Climate Solutions
- ▷ Sustainable Food Systems

Through a partnership between the Center for Innovation in Global Health and the Woods Institute for the Environment, the initiative reaches across the university and beyond to investigate and address these interdependencies to create and preserve a livable future. Areas of focus include:

- Climate & health: Using climate science to protect communities against extreme weather, wildfires, and other impacts of climate change.
- Pollution & health: Envisioning restructured industries that manage ocean, land, and air pollution, support health, and build resilient economies.
- Ecology & infectious disease: Creating solutions that protect and restore ecosystems to reduce emergence of disease-causing pathogens.
- Food, health & the environment: Developing food systems that support livelihoods, mitigate climate change, and promote health—on land and at sea.

This initiative is already well underway, welcoming its second cohort of [Planetary Health Fellows](#) and nearly [50 course offerings](#) on tap for the 2022-23 academic year. Inaugural [Early-Career Research Awards](#) and [Global](#)

# New School, New Initiatives

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[Health Seed Grant Awards](#) provided funding for research efforts led by Stanford-affiliated assistant professors or instructors focused on solutions to complex health challenges involving climate, pollution, global change, food, and the environment.

The [Action Lab for Planetary Health \(ALPHA\)](#) launched three major projects to promote health, environmental stewardship, and social impact – moving Stanford-generated research to action.

## NATURAL CLIMATE SOLUTIONS

The past few years have set new records for heat waves, drought, superstorms, and wildfires, bringing the reality of climate change home to people around the globe. While the toll on people and communities is clear, less obvious is the irreversible damage done to natural systems that could otherwise serve as potent allies in the fight against climate change.

Earth's forests—increasingly at risk from climate-intensified wildfire and pest infestations—are unique in that they can exacerbate the problem or serve as a key solution for climate mitigation. By serving as a net carbon “sink,” they cleanse the air, in recent years absorbing approximately 30 percent of the carbon dioxide released from human activities.

Forests are just one of the natural systems that

play a key role in regulating the Earth's climate, and experts agree there's much to learn about how to better support and increase the ability of forests, oceans, wetlands, prairies, agricultural lands, and other ecosystems to safely absorb and store greenhouse gas emissions. Interventions to support and accelerate these natural processes are often referred to as natural climate solutions (NCS). Natural climate solutions range from reducing deforestation, to stewarding forests to absorb more carbon, to restoring wetlands, to changing farming practices.

Stanford is home to leading scholars in these interconnected areas, and philanthropic



Natural solutions like planting mangrove trees can help make flooding-prone coastlines more resilient to climate change. Credit: chochoway /iStock

investment associated with the new school has opened up new opportunities to expand the university's depth and breadth of expertise.

Thanks to a generous commitment from Toni Cupal and Mike Volpi, we have launched the Natural Climate Solutions Initiative to deepen understanding of how nature-based solutions can:

- Minimize emissions by reducing deforestation and forest degradation; avoiding land use change; reducing fire risk; improving nutrient management in cropland and protecting coastal peatlands.
- Increase CO<sub>2</sub> storage by improving forest management; reducing risk of wildfire; reforestation and creating new forested lands; increasing soil carbon in agricultural and ranch lands; restoring croplands to prairie or savanna; producing biochar; restoring coastal ecosystems; stimulating ocean algae.
- Provide co-benefits such as biodiversity and wildlife habitat; air and water quality; rural jobs; coastal protection; harvestable products; indigenous lifestyles; erosion control; recreation and rural economic opportunities

Findings from Stanford scholars have helped create the foundation of research needed to understand the value and potential of natural

# New School Leadership

*Climate and sustainability are the defining issues of the 21st century. Arguably, there is no other issue that is more important that will affect humanity and the planet.*

Dean Arun Majumdar  
Stanford Doerr School of Sustainability



climate solutions. Faculty, students, and postdocs from the university's schools of humanities & sciences, earth, engineering, and law have made significant strides in assessing the valuable climate contributions of our natural and working landscapes, oceans, and other aquatic ecosystems over decades of research. Stanford scholars play leadership roles in national and international programs through the Center for Ocean Solutions, the Center on Food Security and the



Members of Woods, Precourt, Department of Civil and Environmental Engineering and Stanford Earth communities celebrated the launch of the new Stanford Doerr School of Sustainability on Sept. 1, 2022, when all four entities came together to form the university's first new school in 70 years. Credit: Harry T. Gregory

Environment, the Carbon Removal Initiative, and the Natural Capital Project. The new initiative will build on that core expertise and add new hires in emerging fields to truly integrate ecosystem carbon dynamics, agricultural emissions, soil carbon storage, and forest stewardship and management with public policy and resource management, innovative financial incentives, and effective institutional design—fundamentally transforming the landscape of options for implementing NCS at scale and around the world.

*Addressing climate change and sustainability requires a deep understanding of Earth, climate, and society. Our response to the challenge demands a whole campus effort towards a common goal.*

Dean Arun Majumdar  
Stanford Doerr School of Sustainability



In addition to the announcement of Woods Senior Fellow [Arun Majumdar](#) (Mechanical Engineering, Energy Science and Engineering) as the inaugural dean of the new school, a number

of Woods fellows and affiliated faculty have been selected to serve in Majumdar's leadership cabinet, including:

- Woods Senior Fellow [Jonathan Payne](#) (Geological Sciences) has been named SDSS Senior Associate Dean for Faculty Affairs
- Woods Affiliate [Lynn Hildemann](#) (Civil and Environmental Engineering) has been named Senior Associate Dean for Education
- Woods Senior Fellow Scott Fendorf (Earth System Science) has been named Senior Associate Dean for Integrative Initiatives
- Higgins-Magid Senior Fellow Jenna Davis (Civil & Environmental Engineering) has been named Associate Dean for Integrative Initiatives in Institutes and International Partnerships
- Senior Fellow Rodolfo Dirzo (Biology) has been named Associate Dean for Integrative Initiatives in Environmental Justice

# Catalyzing Research

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Stanford marine biologists, epidemiologists, geneticists, engineers, and others soon will collaborate to develop new water purification technology, build healthier homes, make electric vehicle battery recycling safer, create ocean-friendly sunscreens, and more.

The Stanford Woods Institute for the Environment is awarding \$1.65 million to 10 innovative projects as part of its 2022 [Environmental Venture Projects](#) (EVP) and [Realizing Environmental Innovation Program](#) (REIP) grants. Both programs provide up to \$200,000 per project for interdisciplinary research needed to solve major environmental challenges too complex for any one discipline alone to tackle. EVP grants support high-risk research projects that identify and develop real-world solutions. REIP grants are intended to forward solution-based projects from the discovery phase of research to the validation phase and adoption by end users.

## Environmental Venture Projects (EVP)

EVP grants support interdisciplinary, high-risk research projects that identify and develop real-world solutions.

### The projects selected for 2022

#### DEVELOPING NEW WATER PURIFICATION TECHNOLOGY

This project aims to develop novel resin technologies for the removal and recovery of critical contaminants from wastewaters. The researchers will leverage a platform for high-throughput synthesis and micro-scale screening of large libraries of unique resin materials. Results will help decipher design considerations for selective binding of critical contaminants, generate novel resin technologies with unprecedented efficacy, and yield novel methods for resin development and screening.

Eric Appel (Material Sciences and Engineering), Polly Fordyce (Medicine-Genetics), William Tarpeh (Chemical Engineering)

#### UPGRADING HOUSING INFRASTRUCTURE TO IMPROVE HEALTH AND MINIMIZE EMISSIONS

Researchers will test whether “green” concrete floors made with an alternative cement mix can improve child health while minimizing greenhouse gas emissions in rural Bangladesh. They will also develop guidelines for green concrete floor installation in rural, low-income settings



and model greenhouse gas emissions under scaled up implementation scenarios. The team will engage with nongovernmental organizations in Bangladesh to investigate opportunities to install green concrete floors at scale.

Jade Benjamin-Chung (Medicine-Health Research and Policy), Sarah Billington (Civil and Environmental Engineering), Ali Boehm (Civil and Environmental Engineering), Mike Lepech (Civil and Environmental Engineering)

#### UNDERSTANDING THE THREAT OF WILDFIRE SMOKE-BORNE METALS

Little is known about how fire intensity and soil type affect the transformation of naturally occurring soil- and plant-borne metals, such as chromium, into a toxic state. Researchers will



develop a set of geospatial tools that predicts the threat of toxic chromium generation and downstream exposure, and will determine solutions through mitigation strategies that limit exposure risk to first responders and local communities.

Marshall Burke (Environmental Earth System Science), Scott Fendorf (Environmental Earth System Science), Kari Nadeau (Medicine-Pediatrics)

### INFORMING OPEN OCEAN RESTORATION THROUGH HISTORICAL RECONSTRUCTION

This project will combine biogeochemical, eDNA, and microscopic analyses of sediment cores to quantify the ecological regime shifts in the Southern Ocean, with a focus on the impact of Antarctic whaling—one of the greatest removals of animal biomass ever. The



approach will quantify the pre-disturbance state of one of the most important open ocean ecosystems in the world, and provide a framework for restoration targets in similar ecosystems worldwide.

Jeremy Goldbogen (Biology), Rob Dunbar (Environmental Earth System Science), Liz Hadly (Biology)

### ACCOUNTING FOR WETLAND GREENHOUSE GAS EMISSIONS

Methane emissions from natural wetlands account for up to a third of global methane emissions, yet they remain poorly understood in part because current measurement technology is prohibitively expensive, limited in where it can be deployed and limited in how much spatial and temporal variability it can characterize. With recalibration, low-cost natural gas sensors can provide an accurate alternative. Using this approach, the researchers aim to develop an unprecedented network

of 1,000 low-cost autonomous sensors for deployment in the tropics.

Alison Hoyt (Environmental Earth System Science), Debbie Senesky (Aeronautics and Astronautics)

### CAPTURING AND SEQUESTERING CARBON DIOXIDE IN SOILS

Soil respiration, or decomposition of soil



carbon by microorganisms and respiration by roots, releases carbon dioxide at a rate about 7-8 times greater than fossil fuel burning. This project aims to design a strategy for soil carbon dioxide capture using low-cost, environmentally friendly sorbent materials. The researchers will assess common sorbent materials for

# Catalyzing Research

carbon dioxide sorption under typical soil gas mixtures, determine long-term stability of sorbed carbon dioxide, and develop a model framework for assessment and verification.

Kate Maher (Environmental Earth System Science), Zhenan Bao (Chemical Engineering)

## MITIGATING WATER POLLUTION

Nitrogen pollution affects over 70% of U.S. freshwater and coastal marine ecosystems, costing \$2.2 billion each year in lost livelihoods, recreation, and remediation. This project aims to advance remediation efforts by integrating newly developed nitrogen sensors with machine learning for adaptive sensor control and data analysis on the site, watershed, and eventually regional and national scales.

William Tarpeh (Chemical Engineering), Kate Maher (Environmental Earth System Science), Fio Micheli (Biology), Debbie Senesky (Aeronautics and Astronautics)

## MONITORING URBAN NEIGHBORHOODS TO REDUCE INEQUITIES IN WELLBEING

The researchers will pilot a data infrastructure to aid in examining connections between the natural and visible attributes of urban environments and wellbeing. Based on these analyses, the researchers hope to work with local stakeholders to develop and test interventions that alter

features of the environment aimed at reducing inequality in wellbeing within cities. Interventions that stem from this research can inform solutions to reduce environmental inequities locally and in other cities.

Jackelyn Hwang (Sociology), Hae Young Noh (Civil and Environmental Engineering), Sarah Billington (Civil and Environmental Engineering)

## Realizing Environmental Innovation Program (REIP)

REIP is intended to forward solution-based projects from the discovery phase of research to the validation phase and adoption by end users.

### The projects selected for 2022



## DEVELOPING OCEAN-FRIENDLY SUNSCREENS

The researchers have identified a set of naturally occurring viruses produced by bacteria that can absorb UV light. These materials are safe, structurally stable, completely biodegradable, inexpensive, and non-toxic to human cells or aquatic bacteria. This project aims to develop this technology for use in novel sunscreens that will protect against skin cancers without damaging oceans and reefs.

Paul Bollyky (Medicine-Infectious Diseases), Giulio De Leo (Biology)

## MITIGATING LEAD AND GREENHOUSE GAS EMISSIONS IN EV BATTERY RECYCLING

In South Asia, an estimated 400 million children

are poisoned by lead. To mitigate a primary source of that lead—informal recycling of lead acid batteries from 3-wheeled electric vehicles (EVs)—the researchers have developed a business model for EV garage owners, EV drivers, battery manufacturers and a microfinance organization in Bangladesh. A randomized controlled trial will measure the model's effects.

Erica Plambeck (Business), Steve Luby (Medicine)

## 2021–22 Highlights

### CORAL-SAFE SUNSCREEN

Better characterizing the chemical and biological mechanisms by which sunscreens may harm corals could help guide the development and marketing of effective sunscreens that are coral-safe. Research by investigators on a 2017 EVP-funded project took a significant step toward that goal this past May. Their study, published in *Science*, reveals how a common component of many sunscreens worn by coral reef-exploring tourists may hasten the demise of these endangered ecosystems.

### REIMAGINING WASTEWATER

Research by investigators on a 2019 EVP-funded project reveals how to optimize

electrical processes for transforming sulfur pollution in wastewater, and could help lead to affordable, renewable energy-powered wastewater treatment that creates drinkable water. Their study, published last February in *ACS ES&T Engineering*, paves the way to mining sewage for valuable materials used in fertilizers and batteries that could someday power smartphones and airplanes.



### RECHARGING GROUNDWATER

Massive groundwater extraction in California's Central Valley has created large, unused groundwater storage spaces. This presents an opportunity for a form of managed aquifer

recharge in which excess surface water from winter storms or spring snowmelt is allowed to move into the subsurface and recharge the groundwater system. A 2019 REIP-funded project aims to assess site suitability for the approach through geophysical subsurface imaging and geochemical water quality modeling. Signed into law in September 2021, California Senate Bill 170 allocates \$60 million for floodplain restoration projects, including a portion to support the approach the REIP investigators are developing.

### REDUCING FOOD WASTE

Giving smallholder farmers access to food preservation technology, which is normally too expensive and risky to own individually, could dramatically change the wellbeing of agricultural communities in the developing world. Investigators on a 2019 REIP-funded project aimed at designing, building and testing affordable dryer and cooler prototypes developed a solar-powered technology to improve the quality and quantity of dried agricultural produce. In a study published this past June in *Energy for Sustainable Development*, the researchers detail the approach, which could potentially double profits for smallholder farmers in India.

# Fostering Collaboration

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Cross-sector solutions begin with conversations. This year we hosted experts from a wide range of disciplines for their take on meeting the challenge of climate change equitably. Guests from government, nonprofit, and academic spaces joined Woods Institute and Natural Capital Project conversations to shed light on various populations that will feel the climate crisis most acutely while providing guidance on how we can collaborate to best support the most vulnerable people.

*“It’s not just the bad guys that have to change. Good guys also have to do things differently than we have done before.”*

— *Marcene Mitchell*  
Senior Vice President of Climate Change  
at the World Wildlife Fund

## CONVERSATION WITH BRITT WRAY

Britt Wray, author of *Generation Dread*, spoke with Woods Senior Fellow Michele Barry about the coping mechanisms and strategies we can use to get comfortable with the paralyzing fear that climate change creates while still making progress towards environmental and societal solutions.



“There is an unconscious discomfort, an anxiety, an ambivalence that is evoked by confronting our complicity in holding up these systems that are damaging our planet and making us feel unsafe.”

**Britt Wray**, Human and Planetary Health Postdoctoral Fellow with the Stanford Woods Institute and Stanford Center for Innovation in Global Health  
[Learn More](#) and [Watch the Video](#)

## CONVERSATION WITH SALEEMUL HUQ

Saleemul Huq is an expert on how vulnerable developing countries can adapt to climate change. He spoke with Woods Director Chris Field about the impact that climate change is already having on vulnerable populations and the mentality needed to prepare for and adapt to these inevitable changes.



“In the future, the success of adaptation and the success of even mitigation will be determined by how much loss and damage we can minimize, because we are not going to be able to avert and minimize all of it.”

**Saleemul Huq**, Director of the International Centre for Climate Change and Development (ICCCAD)

[Learn More](#) and [Watch the video](#)

## CONVERSATION WITH ROBERT RIVAS

Assemblymember Robert Rivas has represented California's 30th Assembly District since 2018. Rivas sat down with Woods Institute Director Chris Field to discuss preparing historically under-resourced areas to deal with the impact of climate change.



“So many of the environmental issues and challenges we face as a state impact our communities of color...so having a conversation about environmental progress involves having an honest deliberate and intentional conversation on climate justice and how we can go and meet climate goals and reduce emissions, but at the same time, do so in a way that positively impacts all people.”

CA State Assemblymember Robert Rivas

[Learn More](#) and [Watch the Video](#)

## NATURAL CAPITAL CONVERSATION: WHEN AND HOW WILL NATURE PROVIDE URBAN SOLUTIONS?

Nature-based solutions can mitigate many problems that cities face, but there are barriers to the uptake of these solutions. Five expert panelists from academia and practice joined Natural Capital Project Lead Scientists Anne Guerry (Stanford) and Eric Lonsdorf (University of



Minnesota) to discuss the opportunities to overcome these challenges and do things differently. “The critical (barriers)—lack of money, lack of examples of success, and lack of the data to prove that it worked—we are beginning to overcome all of those things, and that gives me great hope for scaling and replication in the years ahead,”

Todd Garner, director, Cities4Forests and Natural Infrastructure at World Resources Institute

[Learn More](#) and [Watch the Video](#)

## NATURAL CAPITAL CONVERSATION: BRINGING THE VALUE OF NATURE INTO THE ECONOMIC MAINSTREAM

The value of nature is often largely invisible in market economies, even though natural resources are critical to economic success. Panelists joined Natural Capital Project Co-Founder Stephen Polasky (University of Minnesota), to discuss how the integration of global economic



models with ecosystem service models can quantify nature's contribution to the economic bottom-line.

“While benefit cost analysis is critical for thinking about economic efficiency, that is only one decision metric that should be used. It is very reasonable and appropriate to think about things like equity.”

Catherine L. Kling, faculty director at the Atkinson Center for a Sustainable Future (Cornell University).

[Learn More](#) and [Watch the Video](#)

# Cultivating Leaders

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Our Rising Environmental Leaders Program (RELP) returned to in-person Bootcamp this year for the first time since the Covid pandemic began. Twelve fellows traveled to Washington D.C., to meet with a diverse set of speakers from the federal policy community. Highlights of the meetings included: a session on science in federal agencies that included the chief scientist at the U.S. Geological Survey; environmental leaders from the White House Council on Environmental Quality, congressional committee staff, and representatives from leading environmental think tanks and non-profits discussing their work in both producing science and advocating for environmental policy and environmental justice.

Pre-Bootcamp workshops focused on communications and networking skills to prepare fellows for their meetings in Washington and beyond. Fellows, grad students and postdocs from across the campus participated in monthly workshops focused on environmental justice issues and environmental policies that impact disadvantaged communities, such as the just energy transition, access to parks and green space, plastic pollution, and food insecurity.



Credit: Nathan Mitchell Photography

## Hacking for Climate and Sustainability

Austin Stack, a student in Stanford's [Hacking for Climate and Sustainability](#) class this past quarter, thought he had a simple solution to prevent mega wildfires. He was convinced that incentivizing private landowners to preventively burn tree and plant debris before they could fuel the fire was a "no-brainer." So were Stack's project teammates in the class, a new academic offering aimed at developing the skills of a mission-driven entrepreneur by using lean startup principles to tackle a critical environmental challenge. The students envisioned a novel online training module that would help landowners get started with prescribed burns and related reimbursements. Then, idealism collided with reality.

"Believe it or not, people were not down to try prescribed burns on their property near their homes," said Stack, an undergraduate majoring in civil and environmental engineering.

The sobering realization that fear of damage and liability outweighed incentives to prevent fires illustrates the class's premise: effective solutions require deep analysis, as well as feedback and buy-in from those most affected.

"The main idea for the course was to begin to bring more innovation perspectives to sustainability problems," said Brian Sharbono, programs director at the Stanford Woods Institute for the Environment.

Sharbono co-teaches the class with Woods Director Chris Field, Radhika Malpani, and Steve Weinstein. Malpani is founder and former lead of Google Images, and Weinstein is director of H4XLabs, a company that helps



Members of a Stanford student-led team working to increase access to quality electronics repairs in emerging markets stand outside an electronics repairs shop in Narok, Kenya. Left to right: Stanford MBA graduate Sarah Johnson and teammates Ritah Wangila and Ketan Tailor. Credit / Urbanus Wambua

tech entrepreneurs develop companies. The teaching team instills the class with the lean launchpad approach developed by Weinstein and Steve Blank, an adjunct professor in Stanford's Department of Management Science and Engineering. The methodology tests and develops business models through customer interactions.

Teams in the class focused on challenges ranging from decarbonizing buildings to transitioning vehicle fleets to electric powertrains.

"I chose (this class) because I wanted to dive into the climate space—a space that was fascinating but unfamiliar to me, and I was eager to do something more creative and collaborative," said Claire Lior Rosenfeld, a masters student in management science and engineering. "Now I feel like I better understand the mindset of an entrepreneur in this space, and I'm much more well-versed in climate tech."

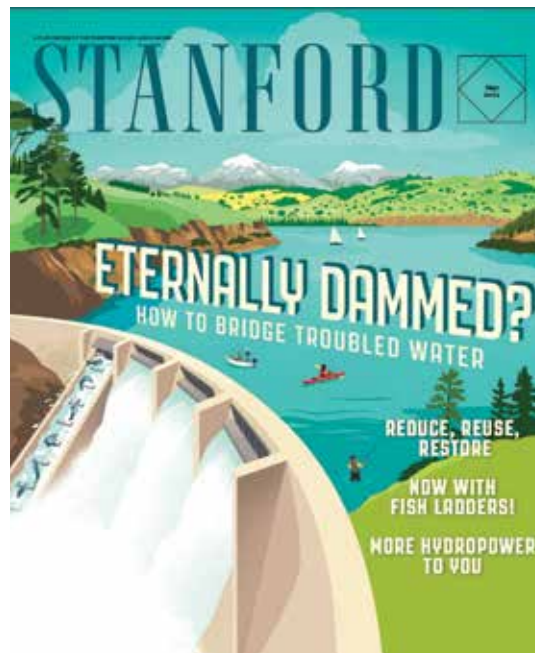
For his part, Stack remains inspired to keep trying. "I still don't really know what I want to pursue career wise, but I know it will be in sustainability," Stack said. "This class was a great sampler of what that could be."

# Connecting Research to Action

The Stanford Woods Institute for the Environment connects research to action by engaging with resource managers, practitioners, and decision-makers in the U.S. and abroad to increase relevance, uptake, and reach of Stanford's environment and sustainability research. The institute's policy and engagement staff work with Stanford scholars in Washington, D.C., and Sacramento to provide legislative leaders and their staff with the findings and decision-support tools to inform development of policy and management practices.

Convening experts and affected communities with diverse interests is central to co-developing practical solutions to pressing environmental concerns. Uncommon Dialogues are the Institute's signature method for convening cross-sector subject matter authorities and stakeholders to surface and analyze research findings, economic influences, social insights and market or policy-based solutions to address specific environmental challenges.

In May 2022 [Stanford Magazine](#) featured one of our most successful dialogues to date—a 2+ year effort that yielded a landmark agreement between the hydropower industry and conservation interests long been at odds over the nation's dams. Woods Senior Research Scholar Dan Reicher



and other members of the working group that emerged from those dialogues provided key insights that formed the basis for funding provisions related to dams and hydropower in the Infrastructure Investment and Jobs Act. That

funding will provide more than \$3 billion to fund improvements to make more electricity as well as removal of outdated dams.

Woods launched another series of Uncommon Dialogues in FY21-22. Focused on a national climate resilience strategy, this series was organized in cooperation with a consortium of partners that includes the Duke Nicholas Institute for Energy, Environment, and Sustainability; American Geophysical Union (AGU); National Academies of Science, EcoAdapt and American Society of Adaptation Professionals. The series aims to explore ways in which academia and the nonprofit sector can help facilitate the eventual adoption of a comprehensive U.S. climate adaptation strategy.

Read more highlights from the past year's policy and engagement efforts:

## HIGHLIGHTS

Woods staff organized several public webinars on topics that brought together our scientists with influential policy and decision makers, allowing us to establish our researchers as a resource while also reaching a broad policy audience. These webinars included topics of Building Electrification featuring Woods Senior Fellow and Professor Rob Jackson (SDSS) and Woods Research Scholar Michael Mastrandrea



as panelists as well as keynote remarks by U.S. Senator Martin Heinrich (D-NM), who is a leading voice in Congress for electrification.

- Woods scholars served on several occasions as trusted resources to policy makers on the topic of extreme heat. Woods Senior Fellow Marshall Burke (SDSS) and Woods Senior Research Scholar Michael Wara met with CA Assemblymember Robert Rivas' office staff to discuss extreme heat effects. They were instrumental in helping them to review and shape the resulting legislation, [AB-1643](#) which the Governor has signed into law. Wara also testified as an expert witness at a California State Assembly hearing on the extreme heat bill. Extreme heat was the topic of the first in a new series of climate inequities webinars Woods is convening on climate change, extreme events, and environmental justice (see inset photo). Woods also reached out to Gary Shaw (SOM), who met with Assemblymember Dr. Joaquin Arambula's staff to discuss perinatal heat effects for a proposed bill, [AB-2420](#), now also signed into law.
- Other forums for engaging cross-sector interests at the state level include the policy and engagement team's organization of a round table focused on California's priority

conservation effort, the 30x30 Initiative. Woods brought together state leaders and key faculty representing all seven schools, who subsequently signed on to a letter recommending science-based decision making.

- Woods helped facilitate recorded interview videos between Wood Senior Fellow Gretchen Daily (H&S) and Landreth Visiting Fellow Felicia Marcus with Assemblymember Rebecca Bauer-Kahan, new chair of the Assembly Water, Parks and Wildlife Committee, on biodiversity/ecosystem services and water issues. These videos were used to inform the members about these topics as well as educate her constituents. Rob Griffin from the Natural Capital Project connected with CA Ocean Protection Council staff to discuss offshore wind development and its impacts on fisheries. Woods Senior Fellow Debbie Sivas (Law) spoke with staff on the Senate Natural Resources Committee about oil spills and offshore production issues.
- Wildfire poses an increasingly important environmental challenge for California and the West. Woods staff and scholars increasingly are called on to brief key congressional and state legislature offices on Stanford research related to wildfire and wildfire smoke health impacts. This past year Michael

Wara and Senior Fellow Kari Nadeau (SOM) spoke with CA Senator Alex Padilla's staff and the House Science Committee requested input on a bill they introduced, [the National Wildland Fire Hazards Reduction Program Act](#). Nadeau also spoke with Senator Heinrich and Congresswoman DeGette's offices.

- Michael Wara's work to brief California state leadership has been particularly useful to CA State Sen. Bill Dodd, who developed legislation that would implement a \$20 million fund to pay for prescribed fire damages to neighboring properties through 2028. The bill – SB 926 – received almost unanimous support from the state legislature, and awaits Gov. Gavin Newsom's signature before it is finalized. "This bill is a pilot. It's intended to see what happens, see what we can learn," Wara said. "This is a targeted, surgical intervention to help a particular set of people who we think could play an important role in reducing risk. I think of them as the Good Samaritans of fire. They are going out on their weekends, getting paid nominal money if anything, and working to make their communities safer... A lot of this is aimed at protecting small-town California. These places where there's a lot of risk, you've also got lots of private landowners."

# Research Centers & Programs

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The Stanford Woods Institute for the Environment supports strategic research centers and programs designed to tackle major environmental challenges facing the planet. These interdisciplinary initiatives leverage Stanford's particular strengths to solve cross-cutting sustainability challenges at the intersection of climate change, food security, freshwater and public health and the demands of a growing population on the natural systems that support life on earth. Read on for selected 2021-22 highlights and publications from our hosted centers and programs.

## Climate and Energy Policy Program (CEPP)

CEPP operates at the interface of policy analysis, academic research and education and stakeholder engagement. By collaborating with external partners in the government, private and nonprofit sectors, the program offers Stanford students and faculty an opportunity to directly engage with and solve real energy and climate policy problems while integrating interdisciplinary research with direct policy engagement.

Faculty Director: Michael Wara

[woods.stanford.edu/climate-and-energy-policy-program/overview](https://woods.stanford.edu/climate-and-energy-policy-program/overview)



### HIGHLIGHTS

- CEPP made substantial contributions to wildfire policy in California that have positioned Woods as a leader in academic-to-policymaker translation and engagement. CEPP Director

Michael Wara assisted California State Sen. Bill Dodd (D-Napa) in the development of two pieces of legislation that remove liability obstacles to prescribed burning. The first, SB 332, limits liability of prescribed burners under specified conditions. The second, SB 926, implements a \$20 million Prescribed Fire Claims Fund to cover losses through 2028 from prescribed fires conducted by private landowners and other nonpublic entities.

- CEPP created experiential learning opportunities for Stanford graduate students and timely analysis for policy partners by organizing the Smoke Policy Practicum, an interdisciplinary policy lab course taught with Professor Debbie Sivas, Director of the Stanford Environmental and Natural Resource Law and Policy Program. Projects chosen with policy partners—including state government partners, the Karuk Tribe, and prescribed burn practitioners—supported the wildfire policy work described above. Work from the Smoke Practicum inspired the Air Resources Board to announce a new rule on air quality permits for prescribed fire—the first since 2003.
- CEPP helped the California Energy Commission (CEC) develop solutions to the intertwined challenges of decarbonization, climate resilience, and energy reliability. Research Director Michael Mastrandrea serves as

Chief Advisor for Energy and Climate Research at the CEC, advising CEC staff and leadership on research and investments to improve energy resilience in a changing climate, climate change impacts on demand forecasting and electricity sector planning, gas system decommissioning, and CEC's contributions to California's Fifth Climate Change Assessment.

- A CEPP whitepaper on the costs of building decarbonization policy proposals formed the basis for a Woods webinar on Electrification of the Building Sector: Constructing an Equitable Transition, involving U.S. Senator Martin Heinrich (D-NM), Co-Chair of the Bicameral Electrification Caucus, as well as experts from Woods, CEPP, and Rocky Mountain Institute.
- CEPP secured funding from the The William and Flora Hewlett Foundation and the Stanford Sustainability Accelerator to expand its wildfire policy work and its work on equitable building decarbonization and community resilience in the energy transition, in collaboration with Stanford faculty and policy partners. CEPP was also part of a team that secured funding from the Precourt Strategic Energy Research Consortium to develop an integrated model

of the electricity and natural gas system that will be used to evaluate decarbonization strategies and policy proposals.

- CEPP worked with Stanford graduate students and environmental justice organizations to provide input to the California Air Resources Board 2022 Draft Scoping Plan, which maps out California's strategy for meeting its globally ambitious, economy-wide greenhouse gas emission reduction targets.
- CEPP provided timely analysis to multiple members of the U.S. House of Representatives, the U.S. Senate, and the California State Senate on issues related to wildfire policy and grid reliability.

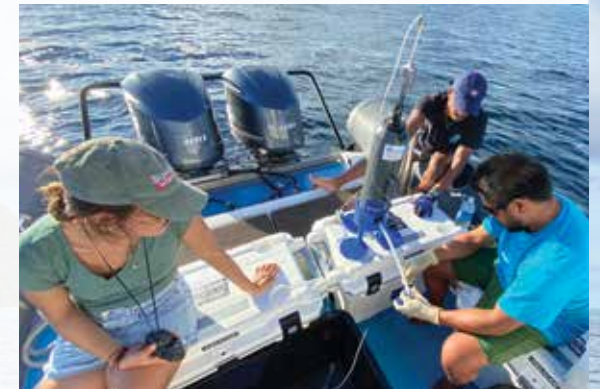
### Center for Ocean Solutions (COS)

The Stanford Center for Ocean Solutions (COS) catalyzes research, innovation, and action to improve the health of the oceans for the people who depend on them most. The Center capitalizes on Stanford's deep expertise in ocean science and in the many other disciplines crucial to solving ocean problems including engineering, computer science, political science, design, and business. By translating research insights into solutions

at scale for oceans and people, the Center is building a generation of leaders who are equipped to work across disciplines and sectors.

Co-Directors: Jim Leape, Fiorenza Micheli

[oceansolutions.stanford.edu/](https://oceansolutions.stanford.edu/)



### HIGHLIGHTS

- Following the launch of the [Blue Food Assessment](#), COS and partners have continued to elevate the [role of blue foods](#) in policy discussions about food systems transformation. COS participated in [COP26](#), [Our Ocean](#), and the [UN Ocean Conference](#) in Portugal, where it supported the launch of the [Aquatic/Blue Food Coalition](#) to bring together governments and NGOs in support of blue food initiatives around the world. COS is also co-leading two [Sustainability](#)

# Research Centers & Programs

[Accelerator projects on blue foods](#): one to build a blue food initiative with Pacific Island states, and another to scope opportunities for developing sustainable aquaculture in Africa.

- COS has continued to engage with partners in Palau to [optimize environmental DNA detection](#) in marine waters for biodiversity monitoring, [develop training materials](#) for data management and visualization, investigate the role of [digital platforms to empower small-scale fishers](#), and assess adaptive management strategies for the Palau National Marine Sanctuary. COS also initiated a three-year project sponsored by the Global Environment Facility with regional partners to advance the objectives of the [Micronesia Challenge 2030](#).
- Through a collaboration with the Stockholm Resilience Centre, Global Fishing Watch, Lancaster University, and the University of Nottingham Rights Lab, COS scientists developed a [new modeling approach](#) that combined machine learning and expert surveys to map regions and ports most at risk for labor abuse or illegal, unreported, and unregulated (IUU) fishing, and identified opportunities for mitigating these risks. COS is working closely with [SeaBOS](#), an initiative of 10 of the largest seafood companies in the world, to help some of their companies use

these results in their procurement practices.

- COS released its first [report](#) on the “Supply Chain Risk Project,” a collaboration with Global Fishing Watch, FishWise, and the World Economic Forum. The team conducted pilot studies to ascertain how satellite data that tracks fishing vessels on the ocean, com-



bined with other publicly available data, might enable companies to avoid products associated with IUU fishing and instead source from sustainable and ethical supply chains.

## SELECTED PUBLICATIONS

A scientific synthesis of Marine Protected Areas in the United States: Status and recommendations. *Frontiers in Marine Science*

Evolving perspectives of stewardship in the seafood industry. *Frontiers in Marine Science*

Local practices and production confer resilience to rural Pacific food systems during the COVID-19 pandemic. *Marine Policy*

Revealing global risks of labor abuse and illegal, unreported, and unregulated fishing. *Nature Communications*

Scientific mobilization of keystone actors for biosphere stewardship. *Nature Scientific Reports*

Sharing the seas: A review and analysis of ocean sector interactions. *Environmental Research Letters*

The role of seafood in sustainable diets. *Environmental Research Letters*

The vital roles of blue foods in the global food system. *Global Food Security*

## Program for Disease Ecology, Health and the Environment (DEHE)

DEHE, a joint initiative with Stanford’s Center for Innovation in Global Health, draws on Stanford experts in public health, technology, engineering, computer science, medicine and the social sciences to discover ecological solutions to humanity’s health challenges and to develop the next generation of planetary health innovators.

**Faculty Director: Giulio De Leo**

[ecohealthsolutions.stanford.edu/](https://ecohealthsolutions.stanford.edu/)

- DEHE has been a key partner in the development of a strategic plan for the Stanford Doerr School of Sustainability’s Human and Planetary Health Accelerator through a comprehensive process that included a series of highly attended workshops on research, education, and impact.

- DEHE has been instrumental in developing popular undergraduate and graduate courses on human and planetary health, as well as designing an environmental sustainability course offered for the first time in Fall 2022. Enrollment for the new course filled up within 12 hours of being offered.
- DEHE lead Giulio De Leo was the invited speaker for a seminar on the biological control of schistosomiasis hosted by the International Society for Neglected Tropical Disease in September 2021.
- De Leo was appointed co-chair of the Engineering Working Group of the Global Schistosomiasis Alliance in April 2022.

## SELECTED PUBLICATIONS

Planetary Health impacts of pandemic coronaviruses. *Frontiers in Public Health*

Environmental Persistence of the World's Most Burdensome Infectious and Parasitic Diseases. *Frontiers in Public Health*

Influence of Socioeconomic and Environmental Determinants of Health on Human Infection and Colonization with Antibiotic-Resistant and Antibiotic-Associated Pathogens: A Scoping Review. *Surgical Infections*

The Potential for Aquaculture to Reduce Poverty and Control Schistosomiasis in Côte d'Ivoire (Ivory Coast) during an Era of Climate Change: A Systematic Review. *Reviews in Fisheries Science & Aquaculture*

Deep Learning Segmentation of Satellite Imagery Identifies Aquatic Vegetation Associated with Snail Intermediate Hosts of Schistosomiasis in Senegal, Africa. *Remote Sensing*

Filamentous Bacteriophages and the Competitive Interaction between *Pseudomonas aeruginosa* Strains under Antibiotic Treatment: a Modeling Study. *MSYSTEMS*

Human-mediated impacts on biodiversity and the consequences for zoonotic disease spillover. *Current Biology*

Three reasons why expanded use of natural enemy solutions may offer sustainable control of human infections. *People and Nature*

## Center on Food Security and the Environment (FSE)

FSE, a joint effort with the Freeman Spogli Institute for International Studies, addresses the challenges of feeding the world's growing population without depleting the planet's natural resources. FSE's team of interdisciplinary scholars addresses global hunger, poverty and environmental degradation by generating vital knowledge and policy-relevant solutions. Scholars with expertise in economics, political science, biology, civil and environmental engineering, law, earth science, medicine, anthropology, education and history are engaged in more than 20 research projects. They offer courses for graduate and undergraduate students interested in issues of hunger, rural development, global resource and environmental degradation, agricultural technology, climate impacts on food security, and agricultural trade and policy.

**Faculty Director: David Lobell**

**Deputy Director: Marshall Burke**

[fse.fsi.stanford.edu/](https://fse.fsi.stanford.edu/)

## HIGHLIGHTS

- By using machine learning and satellite data to monitor crops, FSE researchers found that removing nitrogen oxides—gases found in car exhaust and industrial emissions—could lead to dramatic gains in crop yields. The findings have important implications for increasing agricultural



output and analyzing climate change mitigation costs and benefits around the world.

- The Blue Food Assessment is a joint initiative led by FSE and the Stanford Center for Ocean Solutions intended to understand the role of blue foods in global food systems and propel change that will shape the future of the seafood industry.

# Research Centers & Programs

Along with the assessment, BFA produced two briefs for seafood companies and food retailers, which include recommendations for actions to be taken by seafood companies and retailers or food service compa-



nies to support the uptake of sustainable blue foods. Understanding the demand for aquatic foods is critical for assessing our current and future role in global food systems.

- FSE researchers developed an artificial intelligence model for predicting dangerous particle pollution to help track wildfire smoke in the United States, particularly in the Western states. The detailed results, published in *Environmental Science & Technology*, show millions of Americans are routinely exposed to pollution at levels rarely seen just a decade ago. The Stanford model can help researchers

better understand social impacts from wildfire smoke pollution and inform air quality regulation and wildfire mitigation efforts.

- The National Academy of Sciences awarded the 2022 Prize in Food and Agriculture Sciences to FSE Director David Lobell for his work on the effects of climate variability and change on global crop productivity.

## SELECTED PUBLICATIONS

Two shifts for crop mapping: Leveraging aggregate crop statistics to improve satellite-based maps in new regions. *Remote Sensing of Environment*

Blue food demand across geographic and temporal scales. *Nature Communications*

Using satellite imagery and machine learning to estimate the livelihood Impact of electricity access. *National Bureau of Economic Research*

Combining GEDI and Sentinel-2 for wall-to-wall mapping of tall and short crops. *Environmental Research Letters*

Associations between wildfire smoke exposure during pregnancy and risk of preterm birth in California. *Environmental Research*

Globally ubiquitous negative effects of nitrogen dioxide on crop growth. *Science Advances*

Exposures and behavioral responses to wildfire smoke. *Nature Human Behavior*

Using conditional cash payments to prevent land-clearing cautionary findings from Indonesia. *Agriculture*

## Global Freshwater Initiative (GFI)

GFI is an interdisciplinary research effort that studies the long-term viability of freshwater supplies for people and the environment. The program focuses on developing and water scarce regions throughout the world, and considers threats from climate change, shifts in land use, increasing population and decaying infrastructure. GFI focuses on freshwater vulnerability in a variety of water use sectors, with concentrated study on Jordan and India. The program has also continued to work on water resources in Colorado and ecohydrologic problems in Canada and globally.

**Faculty Director: Steven Gorelick**  
[globalfreshwater.stanford.edu](http://globalfreshwater.stanford.edu)

## HIGHLIGHTS

- GFI researchers, including hydrologists, economists, and urban sociologists, developed



a detailed coupled human-natural systems model to evaluate the effectiveness of policy interventions that can improve freshwater sustainability in India. Their projections of climate and demographic/land-use changes in the city of Pune, India, suggest that the drought and flooding situations there will become much worse in the coming decades, and that none of various drought sustainability options would overcome the projected impacts of drought and population growth during the next 30 years. In July 2022, GFI researchers presented their findings to over 80 stakeholders representing NGOs, academia, government, industry, and consultancies in Pune.

- Using satellite remote sensing and farmer crowd-sourced geo-referenced data, a mapping effort headed by graduate student Ju Young Lee in the Indian state of Maharashtra constructed sugarcane maps far more accurate than previous such maps. The project's results suggest there is twice as much sugarcane—a highly water-intensive plant—grown than reported by the Indian government. This work was presented in the journal *Remote Sensing*.
- Using a hydro-economic model they developed of the evolution of the water tanker

market that services the highly populated Amman, Jordan, region, GFI researchers found that the market is over ten times the size of the government sanctioned market. The researchers also used the model to project the tanker market under climate and population changes in coming decades. They shared these results with officials at Jordan's Ministry of Water and Irrigation. The research is under revision for the journal *Nature Sustainability*.

- Professor Steven Gorelick and two post-doctoral scholars are developing a Colorado River decision-support model that conservation organizations can use to cost-effectively select water market transactions that restore fish habitat, increase interstate deliveries, and maintain agricultural economies. Results will inform Upper Colorado River basin demand management and 2026 Colorado River management guidelines, and be useful to conservation organizations focused on prioritizing water transactions to achieve multiple benefits.

### SELECTED PUBLICATIONS

Capturing Stakeholders' Challenges of the Food-Water-Energy Nexus—A Participatory Approach for Pune and the Bhima Basin, India. *Sustainability*

Mapping Sugarcane in Central India with Smartphone Crowd-sourcing. *Remote Sensing*

Unexpected growth of an illegal water market.

*Nature Sustainability*

Stakeholder workshops informing system modeling—analyzing the urban food-water-energy nexus in Amman, Jordan.

*Sustainability*

### The Natural Capital Project (NatCap)

NatCap pioneers science, technology, and partnerships that enable people and nature to thrive. This Stanford-led partnership works through purposeful engagement and uses cutting-edge science and technology to drive a global transformation towards sustainability. NatCap operates as a global partnership of influential actors in academia, conservation, government, development, private investment, and business. Its powerful network currently includes more than 100 research institutions and 300 implementing partners worldwide, allowing for direct engagements



# Research Centers & Programs

in over 60 countries and for the NatCap InVEST software platform to be used in more than 185 countries.

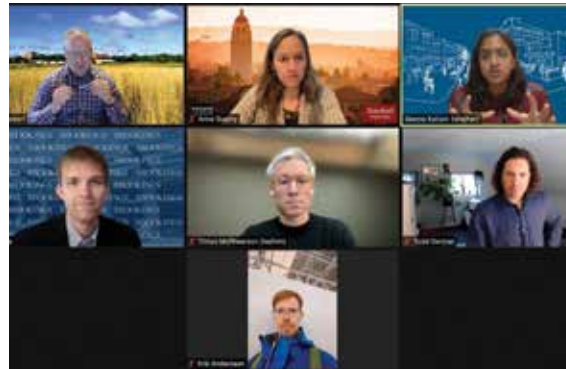
Faculty Director: Gretchen Daily

[naturalcapitalproject.stanford.edu/](http://naturalcapitalproject.stanford.edu/)

- **Scaling natural capital approaches in development planning with the UN GEF.** NatCap analyzed its experiences with the United Nations Global Environment Facility (GEF), identifying key factors for success and barriers to accelerating implementation (report here). The report was a key first step toward the establishment of a Technical Assistance Facility that will build capacity in partner countries and GEF agencies. NatCap is leading a collaboration with the Inter-American Development Bank, the Asian Development Bank, and the GEF to begin capacity building and rapid implementation of natural capital approaches in development planning in 10 pilot countries in Asia and Latin America & Caribbean regions.
- **Advancing science, technology, and partnerships in cities.** NatCap is building user-friendly tools that will help municipal leaders better bring nature into urban planning. Partnerships in US and Chinese cities, in particular, are enabling learning by doing. Key ongoing themes include

better understanding how access to nature improves mental and physical health and exploring the co-benefits of nature-based solutions to sea-level rise in urban areas.

- **Expanding access to InVEST tools and education.** The training team launched a new set of InVEST training tutorials, introducing each model in the InVEST suite and their strengths for natural capital assess-



ments. Another set of instructional videos explores fundamentals necessary to use GIS for InVEST on QGIS & ArcGIS, increasing accessibility to NatCap's spatial modeling tools. Together these educational resources have been watched over 30,000 times. Over the course of the year, NatCapers have led training sessions on NatCap approaches and tools with partners in Belize, China, Switzerland, Sri Lanka, and Zambia.

## SELECTED PUBLICATIONS

Modeling multiple ecosystem services and beneficiaries of riparian reforestation in Costa Rica. *Ecosystem Services*

Embedding the value of coastal ecosystem services into climate change adaptation planning, *PeerJ*

Evidence gaps and diversity among potential win-win solutions for conservation and human infectious disease control, *The Lancet Planetary Health*

25 years of valuing ecosystems in decisions, *Nature*

Protection and restoration of coastal habitats yield multiple benefits for urban residents as sea levels rise, *npj Urban Sustainability*

Nature futures for the urban century: Integrating multiple values into urban management, *Environmental Science & Policy*

Biodiversity and infrastructure interact to drive tourism to and within Costa Rica, *Proceedings of the National Academy of Sciences*

Conservation needs to integrate knowledge across scales, *Nature Ecology Evolution*

The Next Steps for Valuing Nature in Decision Making, Environment: *Science and Policy for Sustainable Development*

## Program on Water, Health & Development (WHD)

WHD's research focuses on the role water plays in advancing global health and well-being. Program researchers pursue topics such as sustainable infrastructure, wastewater and stormwater management, poverty reduction, and health and hygiene education.

Faculty Director: Jenna Davis

[water.stanford.edu](http://water.stanford.edu)



## HIGHLIGHTS

- A study led by Assistant Professor of Chemical Engineering Will Tarpeh and Xiaohan Shao, a research scholar in Civil and Environmental Engineering, revealed a method for transforming sewage into clean, drinkable water. The method, called electromechanical oxidation, could help address the needs of one in four people worldwide who lack access to clean drinking water. Published in *EST Engineering*, the research describes a method of anaerobic filtration that facilitates the transformation of wastewater-based toxic sulfides into safe compounds such as sulfuric acid that can be used in fertilizers and manufacturing processes.
- WHD's Systems Tools for Assessment and Response (STAR) program concluded work on a distance learning program that trained 19 participants in problem diagnosis and response development. Graduates of the program, which received support from the Conrad N. Hilton Foundation, will facilitate better strategic planning, program design, measurement, evaluation and learning in the public, private and nonprofit sectors. Graduates now serve as coaches and are working to apply program principles in Sierra Leone, Kenya, and elsewhere.

- Civil and environmental engineering Professor Alexandria Boehm, postdoctoral scholar Marlene Wolfe, and a team of researchers developed a system for monitoring the prevalence of COVID in campus wastewater. Data gathered were used to predict outbreaks of COVID-19, often several days ahead of trends identified by the university's testing program. The team of researchers used the system in col-



laboration with public health officers on an epidemiology project serving a number of communities across California.

- WHD Director Jenna Davis was named co-editor in chief of *PLOS Water*, an open-access journal that brings together multidisciplinary research relevant to the study of fresh water.

## SELECTED PUBLICATIONS

Desalination Process Design Assisted by Osmotic Power for High Water Recovery and Low Energy. *ACS Chemical Engineering*

Energy-Optimal Siting of Decentralized Water Recycling Systems. *Environmental Science and Technology*

SARS-CoV-2 RNA is enriched by orders of magnitude in primary settled solids relative to liquid wastewater at publicly owned treatment works. *Environmental Science: Water Research and Technology*

The impact of on-premises piped water supply on fecal contamination pathways in rural Zambia. *NPJ Clean Water*

The potential of school-based WASH programming to support children as agents of change in rural Zambian households. *Public Health*

Chlorine Taste can increase simulated exposure to both fecal contamination and disinfection byproducts in water supplies. *Water Research*

Technology Baselines and Innovation Priorities for Securing Water Supply. *ACS ES&T Engineering*

Necessary conditions for sustainable water and sanitation service delivery in schools: A systematic review. *PLOS ONE*

Regional replacement of SARS-CoV-2 variant BA. 1 with BA. 2 as observed through wastewater surveillance. *Environmental Science and Technology Letters*

## Water in the West (WitW)

WitW integrates both science and policy research to develop innovative solutions to key water challenges in California and the American West. Researchers have revealed new insights into improving voluntary water markets, supporting effective implementation

# Research Centers & Programs

of California's Sustainable Groundwater Management Act, and understanding groundwater recharge and quality.

Faculty Director: Barton "Buzz" Thompson  
[waterinthewest.stanford.edu](http://waterinthewest.stanford.edu)

## HIGHLIGHTS

- WitW Landreth Visiting Fellow Felicia Marcus released a [study](#) that assesses the potential for using nature-based solutions (NBS), such as restoring meadows and reintroducing beavers, to help meet state water and climate goals. The study, sponsored by the Walton Family Foundation, provides examples of NBS in use by states in the Colorado River Basin that could serve as models for other states to adopt.
- A [study](#) conducted by Geophysics Professor Rosemary Knight and Geophysics PhD student Matthew Lees simulated 65 years of land subsidence caused by groundwater depletion in California's San Joaquin Valley. Results of the study, published in *Water Resources Research*, suggest that significant sinking—up to tens of centimeters per year—could continue for centuries after water levels stop declining but could slow within a few years if aquifers recover. Land subsidence poses a risk to infrastructure, including

the canals that deliver water to the region.

- Postdoctoral fellow Philip Womble led an [analysis](#) of water transactions in Colorado River Basin states. The results, published in *Environmental Letters*, indicate that legal hurdles thought to impede transactions that keep water in streams to support the environment



frequently take place, initiated largely by government conservation organizations. Scaling these transactions up significantly, Womble concluded, is necessary to support imperiled ecosystems and avoid curtailments for major water users during the ongoing drought.

- A diverse group of stakeholders brought together in a collaborative process organized by Water in the West is nearing agreement on a plan to address water challenges in the

San Joaquin Valley. [The San Joaquin Valley Collaborative Action Program](#) (CAP) expects unanimous agreement from the group's five working groups on their "term sheet," which offers a roadmap to sustainable water use in the basin. The Uncommon Dialogues session, co-chaired by [WitW Director Barton "Buzz" Thompson](#) and co-facilitated by former Landreth Visiting Fellow Tim Quinn, will next turn to implementation of the joint plan.

## SELECTED PUBLICATIONS

Integration of hydrologic remote sensing data to estimate changes in groundwater storage across multiple spatial scales. *Second International Meeting for Applied Geoscience & Energy*

Time-lapse inversion of airborne electromagnetic data for monitoring saltwater intrusion in the Salinas Valley of California, USA. *Second International Meeting for Applied Geoscience & Energy*

Managed aquifer recharge site assessment with electromagnetic imaging: Identification of recharge flow paths. *Vadose Zone Journal*

Assessing the utility of remote sensing data to accurately estimate changes in groundwater storage. *Science of the Total Environment*

Decoupling environmental water markets from water law. *Environmental Research Letters*

Multi-Agency Water Reuse Programs: Lessons for Successful Collaboration. U.S. Environmental Protection Agency

Improved Imaging of the Large-Scale Structure of a Groundwater System With Airborne Electromagnetic Data. *Water Resources Research*

State Climate Policy and Nature-Based Solutions: A Match That Provides Multiple Benefits for Climate, Water, and More. *Water in the West*

## Osa & Golfito Initiative (INOGO)

Rapidly developing regions around the world need thoughtful plans to ensure sustainable futures. The Osa and Golfito Initiative—known by its Spanish acronym INOGO—is an effort to support sustainable human development and environmental stewardship in Costa Rica’s Osa-Golfito region through work with local communities, government, the private sector, and nongovernmental organizations. The goal is to generate a living process for sustainable development led by stakeholders in the region.

**Faculty Directors:** Rodolfo Dirzo, William Durham, Larry Crowder

[inogo.stanford.edu](http://inogo.stanford.edu)

### HIGHLIGHTS

- Through its Experimental African Palm Laboratory (LAPA), INOGO researchers are introducing vanilla plants into oil palm plantations and examining whether production of these plants changes when monocultures are enriched with multiple crops—banana, cacao, and timber trees.
- LAPA researchers completed two thesis projects showing the abundance of amphibians and reptiles is generally greater in diversified oil palm plantations. The research also

showed that species typical of conserved forests are exclusive or more abundant in diversified populations, while species typical of disturbed forests become exclusive or more common in monoculture plots. This result is consistent with that of rodents and insects.



- INOGO researchers Danielle Haulsee and Hannah Blondin completed geolocation tagging on blue marlin and sailfish off the Pacific coast of Costa Rica as part of Project DynaMAR (Dynamic Marine Animal Research), and in support of their research efforts working to disentangle how changes in the oceanography, climate, and human activities impact the distribution and local abundance of these billfish in the Eastern Tropical Pacific. Haulsee and Blondin presented preliminary results describing the

horizontal movements and migrations of these species, as well as their depth use at the international Ocean Sciences Meeting.

- DynaMAR researchers conducted interviews with sport fishers to better understand billfish availability and distribution and the fishers’ perceptions of how changes in the environment and levels of human activity impact these species. The collected data could help identify conflicts, and inform the effective management of the fisheries off the Pacific coast of Costa Rica.
- INOGO is looking into expanding its Stanford Environmental Leadership and Language Program (SELAL), a program to prepare youth for employment in local ecotourism and environmental leadership, into other communities in the Osa and Golfito region and beyond.

### SELECTED PUBLICATIONS

Lizards as a Lens for Understanding the Effects of Land Use Change. Earth Sciences, Stanford University (Outstanding Research Award)

Contrasting herpetofauna diversity in monoculture and polyculture oil palm farms. Earth Sciences, Stanford University  
Where Do the Billfish Go? Using Recreational Catch Data to Relate Local and Basin Scale Environmental Conditions to Billfish Occurrence in the Eastern Tropical Pacific. *Fisheries Oceanography*

# Fellows & Research Staff

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School affiliations noted below reflect the 2021-2022 Academic Year.

## FELLOWS

**Michelle Anderson**, Senior Fellow, School of Law

**Nicole Ardoin**, Senior Fellow, Graduate School of Education

**Jeremy Bailenson**, Senior Fellow, Communication (H&S)

**William Barnett**, Senior Fellow, Graduate School of Business

**Michele Barry**, Senior Fellow, School of Medicine

**Eran Bendavid**, Senior Fellow, School of Medicine

**Sarah Billington**, Senior Fellow, Civil and Environmental Engineering (SOE)

**Barbara Block**, Senior Fellow, Hopkins Marine Station (H&S)

**Alexandria Boehm**, Senior Fellow, Civil and Environmental Engineering (SOE)

**Marshall Burke**, Senior Fellow, by Courtesy, Civil and Environmental Engineering (SOE)

**Bruce Cain**, Senior Fellow, Political Science (H&S)

**Karen Casciotti**, Senior Fellow, Earth System Science (SE3)

**Craig Criddle**, Senior Fellow, Civil and Environmental Engineering (SOE)

**Larry Crowder**, Senior Fellow, Hopkins Marine Station (H&S)

**Yi Cui**, Senior Fellow, Materials Science & Engineering (SOE)

**Lisa Curran**, Senior Fellow, Anthropology (H&S)

**Gretchen Daily**, Senior Fellow, Biology (H&S)

**Jenna Davis**, Senior Fellow, Civil and Environmental Engineering (SOE)

**Guilio De Leo**, Senior Fellow, Biology (H&S)

**Noah Diffenbaugh**, Kimmelman Family Senior Fellow, Earth System Science (SE3)

**Rodolfo Dirzo**, Senior Fellow, Biology (H&S)

**Rob Dunbar**, Senior Fellow, Earth System Science (SE3)

**William Durham**, Senior Fellow, Emeritus, by Courtesy, Anthropology (H&S)

**Paul Ehrlich**, Senior Fellow, Emeritus, Biology (H&S)

**Wally Falcon**, Senior Fellow, Emeritus, Freeman Spogli Institute for International Studies

**Scott Fendorf**, Senior Fellow, Earth System Science (SE3)

**Chris Field**, Perry L. McCarty Director & Senior Fellow, Biology/Earth System Science, (H&S/SE3)

**Chris Francis**, Senior Fellow, Earth System Science (SE3)

**Zephyr Frank**, Senior Fellow, History (H&S)

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**Steven Gorelick**, Senior Fellow, Earth System Science (SE3)

**Lawrence Goulder**, Senior Fellow, Economics (H&S)

**Elizabeth Hadly**, Senior Fellow, Biology (H&S)

**Robert Jackson**, Senior Fellow, Earth System Science (SE3)

**Mark Jacobson**, Senior Fellow, Civil and Environmental Engineering (SOE)

**James Holland Jones**, Senior Fellow, Earth System Science (SE3)

**Rosemary Knight**, Senior Fellow, Geophysics (SE3)

**Charles Kolstad**, Senior Fellow, Stanford Institute for Economic Policy Research

**Alexandra Konings**, Center Fellow, by Courtesy, Earth System Science (SE3)

**Jeffrey Koseff**, Senior Fellow, Civil and Environmental Engineering (SOE)

**Desiree La Beud**, Senior Fellow, Pediatrics, School of Medicine

**Eric Lambin**, Senior Fellow, Earth System Science (SE3)

**Jim Leape**, William and Eva Price Senior Fellow, Center for Ocean Solutions

**Michael Lepech**, Senior Fellow, Civil and Environmental Engineering (SOE)

**Margaret Levi**, Senior Fellow, Political Science and CASBS (H&S)

**Inês Azevedo**, Senior Fellow, Energy Resources Engineering

**David Lobell**, William Wrigley Senior Fellow, Earth System Science (SE3)

**Stephen Luby**, Senior Fellow, School of Medicine

**Kate Maher**, Senior Fellow, Earth System Science (SE3)

**Pamela Matson**, Senior Fellow, Earth System Science (SE3)

**Michael McFaul**, Senior Fellow, Political Science (H&S)

**Fiorenza Micheli**, Senior Fellow, Hopkins Marine Station (H&S)

**Erin Mordecai**, Senior Fellow, Biology (H&S)

**Kari Nadeau**, Senior Fellow, Pediatrics, School of Medicine

**Rosamond Naylor**, Senior Fellow, Earth System Science (SE3)

**Kabir Peay**, Senior Fellow, Biology & Energy Science Directorate (H&S/SLAC)

**Erica Plambeck**, Senior Fellow, Graduate School of Business

**Manu Prakash**, Senior Fellow, Bioengineering (SOE)

**Krish Seetah**, Senior Fellow, Anthropology (H&S)

**Deborah Sivas**, Senior Fellow, Environmental Law Clinic (SLS)

**Sindy Tang**, Senior Fellow, Mechanical Engineering (SOE)

**Barton Thompson**, Senior Fellow, School of Law

**Peter Vitousek**, Senior Fellow, Biology (H&S)

**Leif Wenar**, Senior Fellow, Philosophy (H&S)

**Sarah Fletcher**, Center Fellow, Civil and Environmental Engineering (SOE)

**Gabrielle Wong-Parodi**, Center Fellow, Earth System Science (SE3)

**Eric Appel**, Center Fellow, by Courtesy, Materials Science & Engineering (SOE)

**Hal Mooney**, Senior Fellow, Emeritus, Biology (H&S)

**Julie Kennedy**, Senior Fellow, Emerita, Earth System Science (SE3)

**Terry L Root**, Senior Fellow, Emerita, Humanities and Sciences

**Stefano Ermon**, Center Fellow, by Courtesy, Computer Science (SOE)

**William Abraham Tarphe**, Center Fellow, by Courtesy, Chemical Engineering (SOE)

**Amanda Helen Kennard**, Center Fellow, by Courtesy, Political Science (H&S)

**Alexandra Konings**, Center Fellow, by Courtesy, Earth System Science (SE3)

**Meagan Mauter**, Center Fellow, by Courtesy, Civil and Environmental Engineering (SOE)

**Morgan E O'Neill**, Center Fellow, by Courtesy, Earth System Science (SE3)

**Dustin Schroeder**, Center Fellow, by Courtesy, Earth System Science (SE3)

**Aditi Sheshadri**, Center Fellow, by Courtesy, Earth System Science (SE3)

**Erik Sperling**, Center Fellow, by Courtesy, Earth System Science (SE3)

**Jenny Suckale**, Center Fellow, by Courtesy, Earth System Science (SE3)

To view the full list of 85 Woods Fellows as well as our 202 affiliated Stanford faculty, visit: <https://woods.stanford.edu/people/faculty-researchers>

## Senior Research Staff

(Postdoctoral scholars and students are not listed. For listing of all Stanford researchers affiliated with the Institute, visit: <https://woods.stanford.edu/people/staff>)

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**Lisa Mandle**, Lead Scientist, Natural Capital Project

**Felicia Marcus**, Senior Research Scholar, Stanford Woods Institute

**Michael Mastrandrea**, Research Director, Climate & Energy Policy Program

**Dan Reicher**, Senior Research Scholar, Stanford Woods Institute

**Mary Ruckelshaus**, Managing Director, Natural Capital Project

**Adrian Vogl**, Lead Scientist, Natural Capital Project

**Michael Wara**, Director, Climate & Energy Policy Program, Stanford Woods Institute

**Mele Wheaton**, Senior Research Scholar, GSE & Stanford Woods Institute

# Leadership & Staff

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## RESEARCHERS

More than 85 senior fellows, 202 affiliated faculty, 15 research staffers and 22 postdoctoral scholars are associated with the Stanford Woods Institute for the Environment. For a full listing by research focal areas and contact information, visit the people section of our website:

<https://woods.stanford.edu/people/faculty-researchers>

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## 2021–22 ANNUAL REPORT

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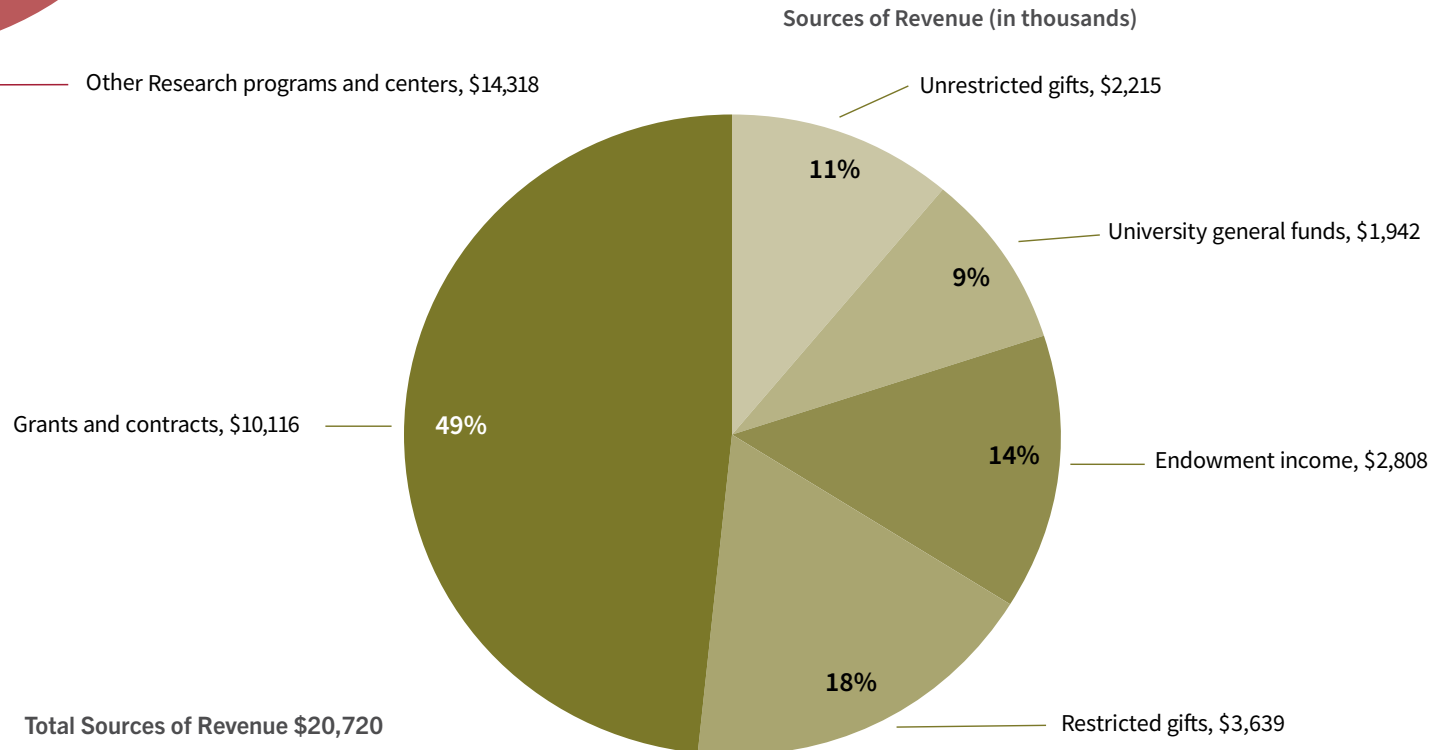
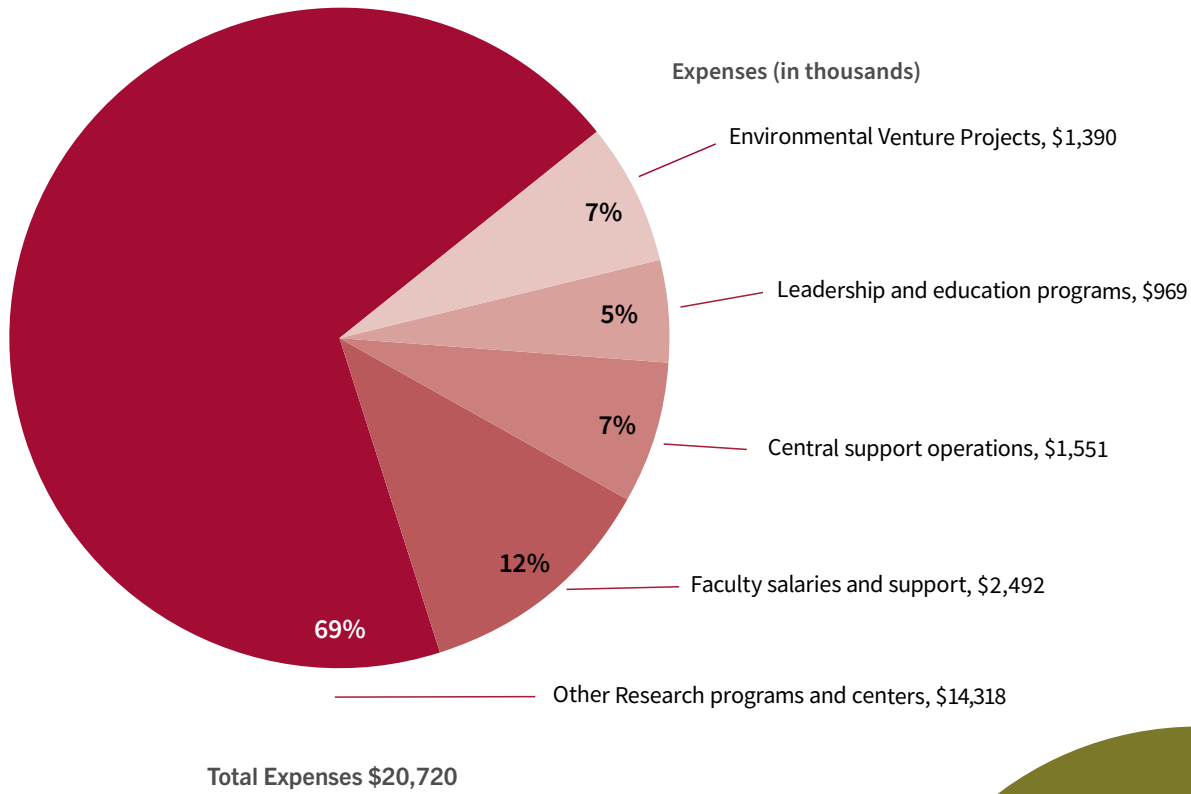
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## FISCAL YEAR 2021–2022

Sources of revenue that supported the Stanford Woods Institute for the Environment in fiscal year 2021–2022 amounted to \$20.7 million, of which 9 percent originated from university general funds, 14 percent from endowment income, 29 percent from gifts, and 49 percent from grants and contracts. Expenses during the fiscal year 2021–2022 amounted to \$20.7 million. Woods' largest expenditure includes Environmental Venture Projects and other research programs and centers, totaling \$15.7 million, or 76 percent of the institute's annual budget.





Back cover photo: Nature-based solutions, such as restoring mountain meadows and reintroducing beavers, show promise for addressing the West's water and climate challenges.

Stanford visiting fellow Felicia Marcus released a report detailing how states are using nature-based solutions to help meet their water and climate goals (see page 26).



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