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Considered one of the most beautiful buildings on campus, Hilgard Hall was designed by John Galen Howard and dedicated in 1917. It was named for Eugene Hilgard, who founded the University Agricultural Experiment Station and served as the first dean of the College of Agriculture, from 1874 to 1904.

In 1982, Hilgard Hall was added to the National Register of Historic Places. Its inscription reads, "To Rescue for Human Society the Native Values of Rural Life."

PHOTO: Rien van Rijthoven

BREAKTHROUGHS

UC BERKELEY COLLEGE OF NATURAL RESOURCES • WINTER 2016

The WATER ISSUE

Working to preserve our world's most precious resource

On the Ground with Water Hot Spots | Environmental Defense Fund

LETTER FROM THE DEAN

Water: It's one of our most precious resources. As California enters its fourth year of one of the worst droughts in the past century, the importance of conserving and caring for our limited supply is ever present to those who live here. Even with this winter's projected "Godzilla" El Niño weather system, droughts will continue to be a part of California's future. Responding to current and future water shortages will require good policy informed by good science. The College of Natural Resources is doing its part on that front, as you'll read in this issue.

Drought isn't the only challenge we face with a natural resource as essential as water. Infrastructure, access, rights, pollution, climate change, and demands from agriculture and urban consumers—along with the needs of wildlife—are all pressing issues the state must address. On page 14, read about four CNR faculty members who have provided some of the critical independent science that is shaping the state's response.

Beyond our state, water is an increasingly critical global issue—one that affects the social, environmental, and economic frameworks of countries worldwide. The Center for Effective Global Action (CEGA) is a unique program that connects scholars from multiple international institutions, and from a variety of fields, to address such challenges. CEGA's goal is clear: to effect social change in some of the most impoverished regions of the world. Starting on page 10, read more about how our CEGA scholars are doing just that.

Water quality is also a powerful determinant of health. This summer the CNR-sponsored Berkeley Water Center hosted a delegation from the Chinese Center for Disease Control and Prevention for an interdisciplinary conference on water and health. The conference brought together a stellar group of UC Berkeley and Lawrence Berkeley National Laboratory water specialists to share their best practices and latest findings on water quality.

CNR's commitment to solving real-world problems is part of what makes it such a special place, and this issue provides many examples of our groundbreaking work.

I welcome your comments at gilless@berkeley.edu.

J. Keith Gilless

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J. Keith Gilless

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14

"Water is the driving force of all nature."
Leonardo da Vinci

COVER PHOTO: *Dudleya lanceolata* is a succulent native to California. To read about how to design a drought-tolerant garden using plants like this one, read recommendations from the College of Environmental Design's Landscape Architecture Department. **Go to ced.berkeley.edu/downloads/courses/2015_SanLorenzo-drought-project.pdf**

WINTER 2016

Berkeley UNIVERSITY OF CALIFORNIA
College of Natural Resources

BREAKTHROUGHS

ONLINE

VIDEO

- Renowned New York food writer Mark Bittman experiences California's agricultural and food scenes in a new 10-part series produced by the University of California and the Berkeley Food Institute.

Go to food.berkeley.edu/mark-bittman-california-matters
Or nature.berkeley.edu/breakthroughs

COVER: Photography by Edward Caldwell; design by Ian Price

Fighting Bad Fat with Good Fat

PHOTO: Jon Dempsmier

As with cholesterol, when it comes to fat, there's a good kind and a bad kind. And UC Berkeley scientists recently discovered how to engineer the growth and expansion of energy-burning "good" fat. This led to findings that such fat actually helped to reduce weight gain and lower blood glucose levels in mice. A study published in the August issue of the journal *Diabetes* may eventually lead to new approaches to combating obesity, diabetes, and other metabolic disorders.

The Berkeley researchers used a specifically tailored hydrogel to "scaffold" and control an implant containing stem cells, in order to form a functional brown-fat-like tissue. While white fat stores excess energy and is associated with obesity, brown fat serves as a heat generator, burning calories as it does its job.

"This is figuratively and literally a hot area of research right now," says **Andreas Stahl,** associate professor of nutritional sciences and toxicology (NST) and the study's senior author. "We're the first to implant in mice an artificial brown-fat depot and show that it has the expected effects on body temperature and beneficial effects on metabolism."

Studies have also shown that cold temperatures can bump up activity in brown fat. Stahl notes, however, that the exposure to cold often leads to increases in food intake as well—potentially negating any calorie-burning benefits from brown-fat activity.

"What's truly exciting about this system is its potential to provide plentiful supplies of brown fat for therapeutic purposes," says study lead author **Kevin Tharp,** an NST PhD student. "The implant is made from the stem cells that reside in white fat, which could be made from tissue obtained through liposuction."

— ADAPTED FROM AN ARTICLE BY SARAH YANG

Environmental Health Hazards Correspond with Racial Disparities

PHOTO: Adobe Stock

In the past, studies have found that neighborhoods with higher percentages of Hispanic and African American residents have poorer air quality, are in closer proximity to hazardous waste sites, or have fewer parks than whiter neighborhoods. Now an online tool has further revealed that those communities hit hardest by environmental hazards can be identified by racial makeup, according to an analysis by UC Berkeley researchers and the California Environmental Protection Agency (CalEPA).

Information on race and ethnicity was obtained from 2010 census data. The median cumulative impact score was 75 percent higher for Hispanics and 67 percent higher for African Americans than for non-Hispanic white populations.

"What's unique about this study is that we're looking at multiple hazards at once and including factors that make populations more vulnerable to the effects of pollution, such as age and disease status," says study lead author **Lara Cushing,** a PhD student in the Energy and Resources Group (ERG). "Still, it's surprising to see such a consistent and stark disparity by race. It was a bigger factor than income."

Published online in the *American Journal of Public Health,* the study used the California Communities Environmental Health Screening Tool (CalEnviroScreen), developed by CalEPA's Office of Environmental Health Hazard Assessment.

CalEnviroScreen utilizes publicly available data on 11 indicators of pollution burden, such as exposure to ozone and pesticides, traffic density, and proximity to hazardous waste sites. The authors also included six indicators of population vulnerability, such as relatively high numbers of elderly and children under five living in the area, lower levels of education among residents, and higher poverty rates.

— ADAPTED FROM AN ARTICLE BY SARAH YANG

PHOTO: Patricia Bubner

Amrita Hazra weeds at the Millet Project, which operates at the UC Gill Tract Community Farm in Albany.

Millet: The Perfect Crop for a State in a Drought

Amrita Hazra, a postdoctoral researcher in the Department of Plant and Microbial Biology (PMB), is on a mission: to introduce people to the benefits of eating millet, which in this country is primarily used in bird feed and as a forage crop for cattle and poultry. Hazra is the leader of the six-member Millet Project team, which, with a Berkeley Food Institute Seed Grant and support from the UC Global Food Initiative's CLEAR Project, is cultivating millets, testing millet recipes, and offering samples of millet-based products at local food events and exhibits.

"California's ongoing four-year drought has united growers, consumers, policy makers, and food activists in the belief that diversity in agriculture and in the food we consume is critically important—we shouldn't be only growing water-intensive monocultures," says Hazra. Millets are robust dryland crops, and many millet varieties are inherently drought-tolerant. They can be grown from seed quite easily at higher temperatures, can grow in skeletal soils, and seldom require synthetic fertilizers. They have a short growing period of 100 to 110 days from seed to grain, and as a result are commonly used as rotation crops. In addition, most millet grains are not easily affected by storage pests.

They're also nutritious, gluten-free whole grains. Different members of the millet family contain different portfolios of nutrients, but millet grains often contain fewer carbohydrates than rice, corn, or wheat and higher levels of proteins, fiber, and minerals such as calcium, magnesium, phosphorous, and iron, Hazra says.

— ADAPTED FROM AN INTERVIEW BY GRETCHEN KELL

NewsMakers

"It's kind of a quiet revolution. Nothing weird or strange has happened, electricity prices haven't shot up or down."

Daniel Kammen, *Professor, Energy and Resources Group; Director, Renewable and Appropriate Energy Laboratory*

On October 5, the *New York Times* quoted Kammen in an article about how California is leading the nation in clean electricity. Solar power arrays in the state produced more energy in 2014 than those in the rest of the country combined, and California is well on its way to meeting or surpassing its 2020 goal for renewable energy.

"The findings indicate that people of color are much more likely than white Californians to be exposed to both environmental and social stressors that impact health."

Lara Cushing, *PhD Student, Energy and Resources Group*

The UPI news syndicate reported on a new study, led by Cushing and published in the *American Journal of Public Health,* revealing that African Americans and Latinos are more exposed to environmental health risks than white populations. (See News, page 2.)

PHOTO: Jesse Kaplan

"Clearing surrounding vegetation is a costly, labor-intensive practice that threatens wildlife habitat. But since it doesn't improve food safety, there's no reason to continue it."

Daniel Karp, *Postdoctoral Research Fellow, Environmental Science, Policy, and Management*

The UPI news syndicate reported that clearing wild vegetation doesn't lead to reductions in pathogens, as previously thought. The report was based on a paper by Karp and ESPM professor **Claire Kremen,** among others, published in the journal *Proceedings of the National Academy of Sciences.* The study explains that such clearing may actually affect farmland negatively—by reducing bee populations, for example, which are vital for pollinating flowering crops. (See On the Ground, page 8.)

Soil Depletion Is Threatening Global Food Security

When it comes to the health of our soils, agriculture is the primary game changer, warns a review paper authored by some of the nation's top soil scientists. Published in the journal *Science*, the paper notes that humans have been depleting the planet's soil resources faster than the nutrients can be replenished. If this trajectory isn't altered, soil erosion—combined with the effects of climate change—will pose a huge risk to global food security over the next century.

"Ever since humans developed agriculture, we've been transforming the planet and throwing the soil's nutrient cycle out of balance," says the paper's lead author, **Ronald Amundson,** a professor in the Department of Environmental Science, Policy, and Management (ESPM). "Because the changes happen slowly, often taking two to three generations to be noticed, people are not cognizant of the geological transformation taking place."

The paper also explains that soil erosion has accelerated since the Industrial Revolution. We're now entering a period when the ability of soil—"the living epidermis of the planet"—to support the growth of our food supply is plateauing. The publication appeared in time for the Global Soil Security Symposium at Texas A&M University, held in conjunction with the United Nations declaration that 2015 was the International Year of Soils.

— ADAPTED FROM AN ARTICLE BY SARAH YANG

PHOTO: Adobe Stock

Plant Immunity Plays a Key Role in Food Security

PHOTO: Adobe Stock

When confronting the challenges to global health, some scientists are tackling the problem from the ground up. Through evolution, plants have developed an array of immunity mechanisms to ward off diseases, including receptors that help them resist infection by disease-causing microbes. Not only can plant disease have an economic impact, but it can also affect our health and natural ecosystems; understanding plant immunity is essential to reducing diseases that can radically alter the production and quality of food. With a rapidly growing global population, losses among important food crops—like potatoes and wheat—can be disastrous.

Now Berkeley researchers have joined a newly funded global effort to improve food security and develop better disease resistance in staple crops that feed the world, including potatoes, tomatoes, mustard greens, and domesticated wheat.

Brian Staskawicz, a professor in the Department of Plant and Microbial Biology (PMB), is one of the researchers who will receive grants from the Two Blades Foundation, a charitable organization dedicated to the discovery, advancement, and delivery of durable disease resistance in crops.

Research teams will investigate the mechanisms used by three major agricultural plant systems—Brassicaceae (crucifers), Solanaceae (nightshades), and Triticeae (domestic wheat and related species)—to resist infection by disease-causing pathogens. They will also develop a publicly available database containing sequence information on the plant species investigated. This open-access database will help other scientists and agricultural agencies around the world to improve disease resistance in plants and better address food insecurity.

— ADAPTED FROM AN ARTICLE BY THE STASKAWICZ LAB

PHOTO: Patrick Gonzalez

Wildfires Are Key Culprit in Greenhouse Gases

Last summer's devastating wildfires in Northern California will have an impact beyond just the forests and communities they destroyed. A new study, published last spring in the journal *Forest Ecology and Management,* quantifies the amount of carbon stored by and released from California forests and wildlands and finds that wildfires and deforestation are contributing more than expected to the state's greenhouse gas emissions.

The study—a collaborative project led by the National Park Service and UC Berkeley—could have implications for California's efforts to meet goals mandated by the state Global Warming Solutions Act (AB 32), whose ultimate objective is to reduce state greenhouse gas emissions to 1990 levels by the year 2020. The bill, which passed in 2006, assumed no net emissions for wildland ecosystems by 2020.

"National parks and other protected areas clearly provide an important function in removing carbon from the atmosphere and storing it," says **John Battles,** the principal investigator on the project and an ESPM professor. "But we also know from previous research that a century of fire suppression has contributed to a potentially unsustainable buildup of vegetation. This buildup provides abundant fuel for fires that contribute to carbon emissions. Meeting the state greenhouse gas targets for 2020 might require a reconsideration of wildland management policies."

Researchers observe that the information available at the time that the bill was passed may have led to underestimates of the amount of carbon released through landmass conversions and wildfires, which are projected to increase in intensity in the western United States due to climate change. The authors point out that California is one of the few jurisdictions in the world to have set mandatory goals for reducing greenhouse gas emissions.

— ADAPTED FROM AN ARTICLE BY SARAH YANG

SUBJECT:

Why I Do Science

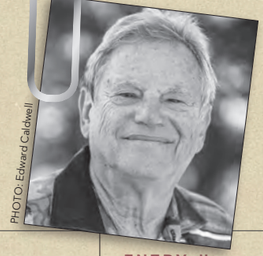


PHOTO: Edward Caldwell

ENTRY BY: **Vincent Resh**

ENTRY #: **014**

My teaching and research are focused on aquatic ecology. I concentrate on using the animals in rivers and lakes to evaluate the effects of pollution and to learn how to control the transmission of human diseases caused by waterborne vectors living in these habitats.

Unlike many of my colleagues, who were interested in science from childhood, I found my focus when I was an undergraduate. I was a philosophy student at Georgetown University in the 1960s, and I remember, during a required science course, suddenly saying to myself, "This is what I want to do with my life."

Graduate school and early research at Berkeley brought me to the tropics, and eventually I began conducting long-term research in West Africa. There I worked on the control of river blindness—a parasitic disease transmitted by biting, river-dwelling blackflies that, at the time, resulted in as many as 30 percent of the local villagers going blind. To them, blindness was just part of their life cycle. I was able to spend several months a year there for 15 years and to see the success of a disease-control program. I was then able to follow this research with 10 years on the Mekong River in Southeast Asia, working to understand the effects of damming that great river for hydropower.

It's an indescribable gift to have a career that directly benefits humans and to teach students who will go out and make a difference themselves. I've been fortunate to teach over 20,000 undergraduates and to have had 40 graduate students complete their training in my lab.

Working in the tropics for so long does have its drawbacks. One of my former students—who's now the expedition physician at the California Academy of Sciences—once drew blood from me. He figured that I've been exposed to most parasites, so I'd be a good place for him to start looking for new ones!

ESPM professor **Vincent Resh** has been a faculty member since 1975 and serves on several international, national, and state science advisory boards focused on environmental and water issues.

Epigenetics: An Important New Term in Drought-Plagued Areas

PHOTO: Adobe Stock

As the effects of climate change are felt in California and globally, an area of increasing concern for agriculture is how plants will survive under conditions of long-term drought. Biotechnology expert **Peggy Lemaux,** cooperative extension specialist in the Department of Plant and Microbial Biology (PMB), is leading a $12.3 million project funded by the U.S. Department of Energy to examine the role of epigenetics in helping plants to survive in drought conditions.

Epigenetics is the study of cellular and physiological trait variations that are caused by external or environmental factors that switch genes on and off. These factors affect how cells read genes, as compared with variations caused by changes in the DNA sequence. Over three years of field-testing, researchers will dissect mechanisms that allow sorghum—a close relative of corn—to survive water deprivation.

"Historically, the genetic manipulation of crops, which has been critical to increasing agricultural productivity, has concentrated on altering the plant's genetic sequence, encoded in its DNA," says Lemaux. "However, recent studies have shown that environmental stresses—in our case, drought—can lead to epigenetic changes in a plant's genetic information. Because these occur without altering the underlying DNA sequence, they allow plants to respond to a changing environment more quickly."

Over the next three years, a variety of observable plant traits will be followed, such as plant height and grain yield. Leaf and root samples will be taken to investigate responses to drought at the molecular level. And researchers will track changes in the sorghum-associated microbial communities.

— ADAPTED FROM AN ARTICLE BY SARAH YANG

Promoting All-Inclusive Sustainability

Across most disciplines and industries, "sustainability" is generally considered a golden term. But for **Isha Ray,** the word is loaded. In many developing countries, the move toward sustainable development discounts the needs of half the population: women and girls. Ray is an associate professor of energy and resources (ERG) and codirector of the Berkeley Water Center, an interdisciplinary consortium of researchers from across the Berkeley campus.

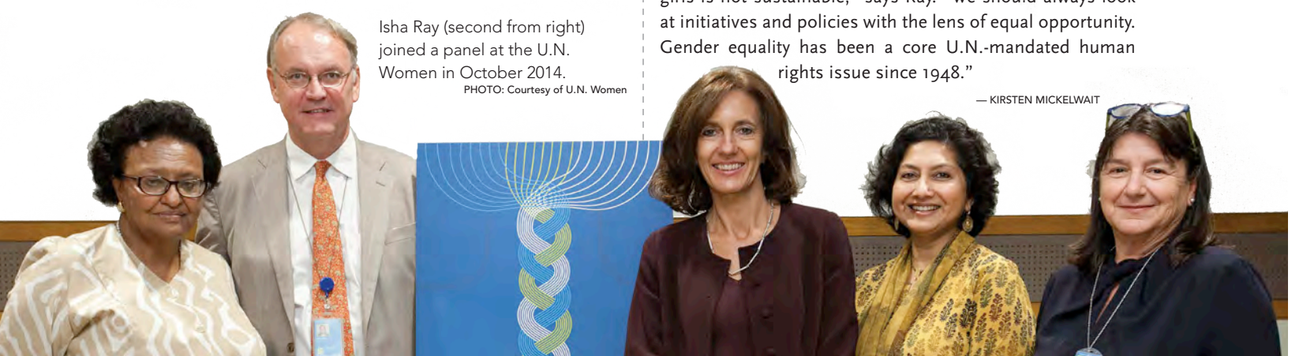
Since 1997, Ray's own research has focused on access to water and sanitation for the rural and urban poor, as well as the role of technology in improving livelihoods. And since 2007, she has studied the connection between women, water, and development. What she's found is that while everyone understands the extreme burden on a community of unsafe water or lack of water, the solutions can interfere with women's opportunities and girls' educations.

Conducting research in Sri Lanka, Turkey, Tanzania, India, Mexico, China, and the Central Valley of California, Ray and her students found that few public water or sanitation systems were being designed with women's bodies and social-biological needs—such as privacy—in mind.

Ray's work in this field led to her being invited to serve on a 2014 panel of experts at U.N. Women, which, in turn, launched the flagship report *The World Survey on the Role of Women in Development* (published in November 2014), with Ray as one of the contributing authors. Findings from that report evolved into a book, *Gender Equality and Sustainable Development* (edited by Melissa Leach and published by Earthscan in September 2015), for which Ray wrote a chapter on transformative social investments.

"Any solution that increases unpaid work for women and girls is not sustainable," says Ray. "We should always look at initiatives and policies with the lens of equal opportunity. Gender equality has been a core U.N.-mandated human rights issue since 1948."

— KIRSTEN MICKELWAIT



Isha Ray (second from right) joined a panel at the U.N. Women in October 2014.
PHOTO: Courtesy of U.N. Women

PHOTO: Courtesy of United Fire Service Women

Female firefighters are "canaries in the coal mine" for breast cancer.

Female Firefighters and Breast Cancer

No one would argue with the fact that firefighters face potential risks every day that they serve on the job. But the possible hazards go far beyond the threat of flames and collapsing buildings. In 2012, the San Francisco Firefighters Cancer Prevention Foundation approached environmental health advocates and the United Fire Service Women about increasingly frequent cases of premenopausal breast cancer among female firefighters.

Thus was born the Women Firefighters Biomonitoring Collaborative Study, led by researchers at UC Berkeley, the Silent Spring Institute, and UC San Francisco, among others. These groups are testing San Francisco women firefighters for chemicals that have been shown to be mammary carcinogens in animals, and comparing the firefighters' exposures with those of women working in other city services.

Because the San Francisco Fire Department has one of the largest ranks of women in the nation—approximately 225—they're the ideal group for this research. It's believed to be the first-ever study of women firefighters to assess exposures to chemicals linked to breast cancer, including combustion by-products and diesel exhaust, flame retardants, and perfluorinated chemicals.

According to principal investigator **Rachel Morello-Frosch**—a professor in the School of Public Health and the Department of Environmental Science, Policy, and Management (ESPM)—the study's greatest innovation is that local firefighters are scientific partners: They codeveloped the study design and are participating in the recruitment of subjects, data collection, biospecimen processing, and grant writing.

"Firefighters are our new canaries in the coal mine, showing the impact of environmental chemicals on our health," Morello-Frosch says. "Women have worked extremely hard to enter the ranks of the fire department. But now they're facing potential hazards in the workplace." Ultimately, the research findings can be compared with documented environmental chemical exposures among women in female-dominated professions, and with the general population. "Firefighters are the ones getting the most intense toxic exposures, but these compounds are also embedded in products that we buy and use every day," Morello-Frosch says.

— KIRSTEN MICKELWAIT

Five Key Lessons

THE ROAD TO PARIS

In December, more than 190 nations met in Paris to try to resolve the world's climate crisis at the 2015 United Nations Climate Change Conference. Over the course of the 23 years and 20 gatherings since the first such talks in 1992, only one legally binding agreement, the Kyoto Protocol, has emerged—a protocol in which two of the world's largest per capita emitters, the United States and Canada, are not participating.

During the fall semester, lecturer and former California assemblywoman **Nancy Skinner** '70 taught ESPM 290, The Road to Paris, a special course leading up to the historic negotiations. Here are five key lessons they explored.

1 **Science should be the driver.** There is clear and visible scientific evidence of a changing climate. We must help to ensure that the solutions pursued are based on sound science.

2 **Think outside the box.** Previous international negotiations have made little headway, but there are new voices—like the People's Climate March, Pope Francis's encyclical, and the Islamic Declaration on Global Climate Change—encouraging a different outcome.

3 **Markets respond to policy.** Public policy and political leadership have helped to drive the market for renewable energy with increased investment, technology breakthroughs, and price reductions. The annual added capacity for renewable power is now larger than for coal, natural gas, and oil combined.

4 **Think globally, act locally.** In the past, we've looked to national governments to solve the crisis. But sub-national governments like California and British Columbia—along with cities active in projects like C-40 and Cities for Climate Protection—are models for action, and grassroots efforts for fossil fuel divestment are emerging around the globe.

5 **Remember land use, food production, and forests.** Emissions reduction isn't just about transitioning from fossil fuels. Retaining the carbon stored in soils, grasslands, and forests is essential, as is reversing deforestation and land-use changes driven by food and fuel production.

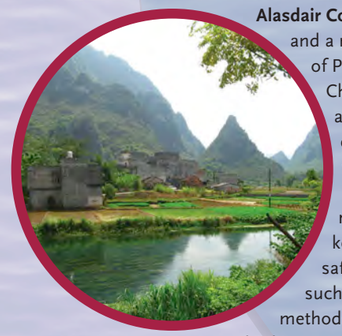
ON THE GROUND

A SAMPLING OF RESEARCH IN

Water HOT SPOTS Around the World

Zachary Burt, an Energy Resources Group (ERG) postdoctoral candidate, is researching drinking-water intervention projects—specifically users' preferences, their willingness to pay for the resource, and the projects' net benefits—as well as studying gender and sanitation issues. *India, Tanzania*

A study being led by Nature Conservancy researchers and UC Berkeley faculty—including fish ecologist **Stephanie Carlson,** associate professor of environmental science, policy, and management (ESPM)—has emphasized that a key victim of illegal marijuana production is California's environment, particularly in sensitive watersheds already stressed by the state's ongoing drought. *Northern California's Eel River*



Alasdair Cohen, an ESPM PhD candidate and a master's candidate in the School of Public Health, worked with the Chinese Center for Disease Control and Prevention (CCDC) to conduct extensive research on drinking-water treatment in rural China. His research, which revealed that rural households using electric kettles to boil their water had the safest drinking water, was the first such study in China to evaluate the methods that households use to treat drinking water. *China*

Stella Cousins, an ESPM PhD candidate, is working on a global-scale drinking-water project through the National Socio-Environmental Synthesis Center, which investigates ties between the social, political, and environmental characteristics of urban water supplies. Understanding the factors that enable payments for watershed services initiatives may ultimately help protect drinking-water supplies for cities worldwide. *Australia, China, Ecuador, Kenya, and the United States*

Yoshika Crider, an ERG PhD student, is developing and adapting low-cost chlorination technologies that would work at community water-collection points, as well as researching practical ways to ensure low-cost, safe drinking-water access for the urban poor. *Bangladesh*

Caroline Delaire, a PhD student in civil and environmental engineering (CEE), is working under Professor **Isha Ray** (ERG) on access to safe water in the Bengal basin, where groundwater is heavily contaminated with arsenic. Her research looks at household behavior change in arsenic-affected communities and at the use of alternatives to arsenic-contaminated groundwater. *India, Bangladesh*

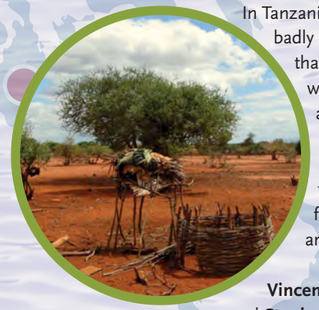
With the intensification of agriculture, pesticides and other pollutants pose a grave threat to aquatic ecosystems around the world. ESPM PhD candidate **Lisa Hunt** is studying the impacts of insecticides on stream ecosystems, as well as the implementation and effectiveness of landscape-level mitigation measures. *Argentina, Paraguay, Brazil*

Christopher Hyun, an ERG PhD student, is working with NextDrop, an information and communications technology intervention, to provide more reliable and timely information to the people of Bangalore about when and how long they'll get water each day. NextDrop has developed a system that uses text messaging to communicate with the service workers who manually open and close the valves controlling local water supplies, then inform residents when water is coming. *India*

A study led by **Daniel Karp,** a NatureNet postdoctoral research fellow in ESPM and at the Nature Conservancy, has questioned the usefulness of removing non-crop vegetation as a means to reduce field contamination of fresh produce by disease pathogens such as *E. coli*. *California*

Suzanne Kelson, an ESPM PhD candidate, is studying how water flows and temperatures influence the behavior and performance of Pacific salmon. *California*

Morgan Levy, an ERG PhD student and a member of the Sally Thompson Ecohydrology Lab, is conducting a large-scale empirical study of land-use-change impacts on river flow in the Brazilian rainforest-savanna transition region, with relevance to hydropower and agriculture. *Brazil*



In Tanzania, subsistence farmers were badly affected by a two-year drought that destroyed any chance of food or water security. **Deepak Premkumar,** an agricultural and resource economics (ARE) PhD student, has conducted a needs assessment to provide recommendations for future development projects in the area. *Tanzania*

Vincent Resh, ESPM professor, and **Stephanie Carlson,** ESPM associate professor, are comparing similarities and differences in function and management implications in Mediterranean-climate rivers throughout the world. *California, Chile, Mediterranean Basin, South Africa, Australia*

Sixty-eight million people depend on fishing the Mekong River for the bulk of their protein. Mainstream dams already built in China's Yunnan Province and under construction in Laos may devastate fish stocks by blocking migration routes for feeding and spawning. **Vincent Resh,** ESPM professor, has worked with the Mekong River Commission to develop mitigation and management strategies to protect this important food source. *Southern China, Thailand, Laos, Cambodia, Vietnam*

Water scarcity is becoming a major obstacle to meeting growing food demand in semiarid regions of the world. One solution is to reuse treated urban wastewater for irrigation. However, these wastewaters often contain high concentrations of salts that can cause soil degradation. **Garrison Sposito,** ESPM professor, is collaborating with UC Cooperative Extension researchers and other scientists to develop new water-quality guidelines to increase the sustainable use of wastewaters for irrigation. *Australia, Israel, California*

PHOTO: Adobe Stock

Becca Taylor, an ARE PhD candidate working with Professor **David Zilberman,** has studied the adoption of drip irrigation in California. The technology was introduced in 1969; less than 5 percent of farmers had adopted it by 1979, and now it is used on 40 percent of irrigated land. Adoption was triggered by water scarcity, especially during droughts; by the development of cultural practices that accommodate drip irrigation; and by improvements in technology. Drip irrigation has increased yields, saved water, and generated net benefits that are likely to be greater than a billion dollars annually. *California*

ARE professor **David Zilberman** has been involved in projects assessing water systems in developing countries. His research indicates that India and South Asia are depleting groundwater aquifers; measures must be taken to eliminate water subsidies and improve water-use efficiency. In sub-Saharan Africa, water resources are underutilized, and agricultural production can be enhanced by more strategic investment in irrigation. *India, Ivory Coast*

In September, UC Berkeley hosted a delegation from the CCDC to discuss the latest research and developments related to water treatment, water management, disease prevention, and public health.

Among the interdisciplinary water specialists present were **Isha Ray,** ERG associate professor and codirector of the Berkeley Water Center; **Jack Colford,** professor of epidemiology, School of Public Health; **Kara Nelson,** CEE professor; **Ashok Gadgil,** CEE professor and director of the Energy and Environmental Technologies Division at Lawrence Berkeley National Laboratory; and **David Sedlak,** professor of mineral engineering, codirector of the Berkeley Water Center, and director of the Institute for Environmental Science and Engineering.

UC Berkeley and the CCDC are now in discussions concerning the establishment of a formal, long-term research collaboration. *Berkeley, China*

Except where noted, photos are courtesy of individual researchers.

Where Science Meets Activism

The Center for Effective Global Action inspires on-the-ground interventions to change the daily lives of millions

By Nate Seltenrich

PHOTO: Jim Block

Left: Edward Miguel and Temina Madon helped cofound CEGA in 2007.

Chlorine dispensers at water sources in developing countries can markedly reduce the risk of childhood diarrhea. Text-message updates on water availability can save time and money for ultra-poor women and girls faced with unreliable access. Flood-tolerant rice can improve yields and increase economic stability for India's most marginalized farmers.

These are among the findings of recent research from the UC Berkeley–based Center for Effective Global Action (CEGA), but they're not strictly academic. In all three cases, the results have supported or inspired on-the-ground interventions, affecting the lives of millions of people.

Not your ordinary university-based research lab, the eight-year-old CEGA—located in Giannini Hall—is geared toward driving global development policy and programming, often taking its cues from major human rights funders like the Bill and Melinda Gates Foundation, the William and Flora Hewlett Foundation, and the U.S. Agency for International Development. "It's not only trying to disseminate the research and promote the scale-up; I like to say it's steering the ship toward problems that society has recognized," says CEGA executive director and cofounder **Temina Madon.** "We try to be nimble and adaptive and figure out where there are gaps that we can usefully fill."

More than 60 CEGA-affiliated researchers at the University of California, Stanford University, and seven other West Coast universities use rigorous evaluations, data-science tools, and novel measurement techniques to assess the impacts of large-scale social and economic development programs like those above. But their purview extends well beyond water, agriculture, health, and economics to areas including education, labor, infrastructure, and the environment, representing a holistic view of the complex development challenges facing the planet today.

Still, it's not a reach to see water issues as the hub from which the center's core research sectors extend like spokes on a wheel. That's particularly true when one's perspective includes climate change, which is likely to modify precipitation patterns around the globe, exacerbate public health challenges tied to drinking water and sanitation, and—as other high-profile CEGA research has shown—lead to increased human conflict triggered by flooding and drought.

"It's not only trying to disseminate the research and promote the scale-up; I like to say it's steering the ship toward problems that society has recognized.

—Temina Madon, CEGA executive director and cofounder

The Power of Rice

Perhaps no water-related work out of the center has had quite as massive and swift an impact on people's lives as research by College of Natural Resources professors and CEGA cofounders **Alain de Janvry** and **Elisabeth Sadoulet** into a new strain of rice in Southeast Asia. Their 2013 study on the agricultural and economic benefits of a flood-tolerant new variety resulted in heavy investment and widespread distribution by the Indian government. "It is now covering millions of hectares in areas where there is a risk of flooding," de Janvry says. As the initial paper and a second now-pending publication show, that's a huge boon to countless small-scale farmers and their families in eastern India and Bangladesh.

Developed through selective breeding by researchers at UC Davis in collaboration with Indian scientists and the International Rice Research Institute, the new variety is a twist on an old favorite, the regional staple Swarna. Nutritious and high yielding yet prone to fail after flooding, the crop can be a liability to poor

CEGA cofounder Elisabeth Sadoulet PHOTO: Jim Block

farmers working low-lying lands. But a single gene expressed in the new Swarna Sub1 variety allows it to survive all but the most severe flooding.

"The rice stays put and kind of holds its breath underwater, if you like, for up to two weeks," de Janvry says. Once the water recedes, it resumes growing. Through a controlled field experiment, he and Sadoulet quantified this benefit in terms of seasonal productivity as well as farmers' longer-term economic stability. "The idea is that once farmers know they're going to be protected in bad years, then they're going to invest more in their rice every year, knowing that they will be less at risk," de Janvry says.

Both the Problem and the Solution

It's a great success story, but not the only recent example of water-related research leading to widespread deployment of a proven solution in the developing world. A project by Berkeley economics professor and CEGA faculty director and cofounder **Edward Miguel** that began a decade ago by evaluating the health benefits of spring protection in rural Kenya—enclosing spring-fed water sources in pipes and concrete basins to prevent contamination—evolved into the development of an even cheaper plastic chlorine dispenser for use at water sources.

Field-testing revealed that the dispensers, which deliver a small amount of the bacteria-killing chemical for standard-size jerricans, reduced childhood diarrhea rates by about 25 percent. According to the World Health Organization, diarrheal disease is the second-leading cause of death in children under five worldwide, resulting in an estimated 2.2 million deaths every year. Once Miguel's research came out, a number of organizations began rapidly distributing the dispensers throughout Southern and East Africa, Haiti, and South Asia.

Today, more than 2 million people have access to safe water thanks to the devices, and within the next few years the nonprofit Evidence Action aims to increase that figure to 25 million, at a cost of about 50 cents per person per year. "They're really scaling up fast," Miguel says. "They've received a lot of money to do this, and they're reaching out quickly. It's really exciting."

Miguel's work has led to other important research by Berkeley faculty. CEGA affiliate and public health professor **Jack Colford** is coordinating a massive, multinational undertaking called WASH Benefits, designed to generate evidence on the health and developmental benefits of household water treatment, improved sanitation and latrines, hand washing with soap, and nutritional interventions during the first two years of life. Currently, almost no data exist that would allow direct comparison of the benefits or cost-effectiveness of these simple interventions.

Launched in 2009, the $10.9 million, Gates Foundation–funded study includes two randomized controlled trials to measure health outcomes after two years of intervention among more than 10,000 newborns in rural Bangladesh and Kenya. Results are due out late next year.

Diarrhea and other intestinal infections remain a primary target, but they're not the only one. "The hypothesis is that these interventions we're doing are also going to impact the growth of the children, and that potentially has much longer-term benefits," Colford says.

Water plays a complicated role in the equation as both a pathogen exposure route and a potential solution, he notes. Water availability isn't a major problem in either Kenya or Bangladesh, but water quality is critical—whether the water is used for drinking, washing, or sanitation. As Miguel's research on chlorine dispensers showed, about three-fourths of diarrhea cases are unchanged by access to clean drinking water. The task before the WASH study is to quantify the benefits of other approaches, both individually and combined. If history is any guide, the implications could be huge.

A Source of Conflict

It's harder to say how, exactly, we'll respond to thought-provoking findings from Goldman School of Public Policy professor and CEGA researcher **Sol Hsiang** that water access could become an increasingly relevant factor in human conflict and violence as climate change progresses. Evidence reviewed by Hsiang, along with Miguel and **Marshall Burke**, PhD '14 ARE, points to drought having played a significant role in the collapse of the Mayan Empire, the rise and fall of dynasties in China, and the demise of the ancient city of Angkor.

Such upheaval could well happen again, Hsiang says. "With rainfall, climate change is going to cause some places to become drier and others to become wetter. We've observed historically that when you have these extreme rainfall patterns, whether dry or wet, populations tend to engage in more violent behavior. We expect the climate to move more toward the extremes, and we know that the extremes are where we observe higher rates of violence."

Localized examples already exist in the modern world, Hsiang says, including evidence that in India, Hindu-Muslim riots are more common when there's less water, as is domestic violence against women; in the Amazon, land invasions for agricultural uses are more common following periods of abnormally high or low rainfall; and in conflict-ridden areas of Africa, violence also may spike when rainfall is very high or low.

In most if not all cases, Hsiang believes, the link hinges on agriculture and farming, because precipitation extremes can have profound effects on yields, which in turn impact both nutrition and finances.

And that leads back to CEGA's core mission: solutions like rainfall and flood insurance or more drought- and flood-tolerant crop varieties, to keep families afloat during tough times. "We've documented the basic relationship," Hsiang says, "and now we're trying to figure out exactly what's going on, so that we can formulate very specific policies to target these effects."

A GROUP OF "ACTIVIST SCIENTISTS"

At its core, the Center for Effective Global Action's model is simple: Policy makers define priorities, and research affiliates tackle them with the goal of developing, applying, and scaling up solutions. That's been the center's mission from the very beginning, when **Temina Madon**, **Edward Miguel**, **Alain de Janvry**, **Elisabeth Sadoulet**, and three other Berkeley colleagues collaborated on its founding in 2007.

"It was originally this group of what I like to call 'activist scientists'—researchers who were committed to doing research with social impact, and getting a positive public benefit from their results," executive director Madon says. Since then, the vision has expanded significantly:

- CEGA was established with a $410,000 multiyear grant from UC Berkeley. Last year, with a staff of nearly 20, it operated a $6.2 million budget—$4.5 million of which went directly to research.
- Its reach includes a network of 60 top scientists at nine West Coast universities, active trials in more than 40 countries, and 70 investments in 10 sectors.
- CEGA's multidisciplinary work is organized around seven portfolios, most of which touch on water in one way or another: Agriculture; Climate and Environment; Education and Labor; Health; Institutions; Technology and Infrastructure; and Finance and Cash Transfers.
- The center invested more than $850,000 last year in bringing top global talent to Berkeley as research scholars, like Jeanine Condo, head of the College of Medicine and Health Sciences at the University of Rwanda, and Narayan Das, a research fellow with the Bangladesh-based development organization BRAC.
- Since 2010, CEGA has invited 22 such scholars to campus, complementing Berkeley research and Silicon Valley technology with an informed international perspective.

Below: In the state of Uttar Pradesh, women harvest Swarna Sub1, a Stress-Tolerant Rice for Africa and South Asia (STRASA) variety from the International Rice Research Institute. PHOTO: Ellie Turner

CALIFORNIA'S DELTA:
On the Front Lines of the State's
WATER ISSUES

By Zac Unger, MS '00 Environmental Science, Policy, and Management
Photography by Edward Caldwell and Jim Block

On June 3, 2004, a small trickle of water started to flow through a levee on the Jones Tract, a patch of farmland west of Stockton that sits below sea level. Of California's 27 million acres of irrigated croplands, the tract's 12,000 acres weren't exactly at the forefront of anyone's mind. But within a few hours the rivulet had become a deluge, opening a 350-foot-long gash in the wall that was built to hold back the waters of the Sacramento–San Joaquin Delta. The land quickly became a lake, submerging asparagus fields, corn silos, and dozens of homes beneath 60 million gallons of water. Repairing the break required six months of constant pumping and cost approximately $100 million; farmers throughout the Central Valley, who depend on the delta's 1,100-mile-long network of levees, had a new reason to lose sleep at night. The cause of the initial rupture was a beaver, working to expand its home.

California water: Few natural resources are as impressive, or as imperiled. Whether it's supplying 40 million domestic users, cooling the server farms of Silicon Valley, or irrigating the actual farms that supply half of the nation's produce, the importance of the state's aquifers and headwaters cannot be overstated. (Lake Tahoe, Yosemite Falls, and white-water rafting on the Kern and American Rivers feel like an embarrassment of riches.) While the potential for a multi-decade drought has grabbed headlines, however, California's water supply faces assault from a host of lesser-known factors including infrastructure failure, pollution, habitat loss, and plain old political chaos. This issue is strongly interdisciplinary, so it's only natural that College of Natural Resources professors and students have been at the forefront of analyzing the problems and beginning the search for solutions. Several Berkeley professors have even served on the Delta Independent Science Board (DISB), a group of experts appointed by the state to oversee the quality of scientific research on California's contentious delta water issues.

Supply vs. Demand

When asked to name the three greatest threats to California's water, **Richard Norgaard**, professor of energy and resources (and the DISB's first chair, who still serves on the board), couldn't be more clear. "Issue number one, one, and one is that a substantial portion of the acreage in agriculture is supported through groundwater overdraft, even in normal-rainfall years," he says.

According to the U.S. Geological Survey, California's cities, factories, and farms soak up about 38 billion gallons every day. And while most people think of water in terms of rivers, lakes, and rain, over a third of the state's supply comes from aquifers deep underground. Only one in six Californians relies on groundwater alone to supply their domestic needs. "We've been mining water to expand use beyond surface-water allocations," says Norgaard. "Groundwater is close to gone, and agriculture

PHOTO: Edward Caldwell

is saying, 'Where's our water, where's our water, where's our water?'"

Given that much of California is a desert—and that decades-long droughts are not impossible—intelligently managing California's limited supply is crucial. Governor Jerry Brown recently ordered municipalities to cut home water usage by a whopping 25 percent, and California residents gave themselves a well-deserved pat on the back when usage for July 2015 surpassed that target by 6 percent. But there's one problem: Domestic use accounts for only 10 percent of California's total water consumption. Agricultural use, on the other hand, accounts for closer to 40 percent.

At first glance, that doesn't seem entirely inappropriate. Fruits, vegetables, and nuts, not to mention Northern California's incomparable wine and cheese—why shouldn't the farmers who feed half of the nation take half of the water that the state has to offer? "Do you know what percent of the state's economy is agriculture?" asks **Vincent Resh,** a professor in the Department of Environmental Science, Policy, and Management (ESPM) and another DISB member. "Less than 2 percent." It's a very vocal 2 percent, though, and there are volumes of case law—and a good amount of political muscle—dedicated to maintaining the status quo. "I'm very sympathetic toward the plight of farmers in the delta," Resh continues. And farmworkers are the poorest of California's poor, with seasonal unemployment rates reaching upwards of 60 percent. "It's the human side of the story that I've become extremely sensitive about."

Nonetheless, Resh recalls being on a delta tour that was packed with people who identified themselves as delta farmers. "They were all talking about how this has been their family heritage for generations, but they were working as lawyers and bankers. They were really talking about a way of life that was long gone for them personally, but a memory that they were holding on to. Actually, this 'way of life' idea is true of many of the contentious water issues in California. The controversies over who gets the water in the Klamath River in Northern California and Oregon are as much about way of life as they are about water for agriculture and salmon."

A Fragile Water System

Nobody is suggesting an outright end to farming in California, but it's becoming increasingly clear that change is coming. One looming problem is the fragility of the levee system. Drive around Sacramento's rural environs and you'll realize that a lot of farmers actually do their work below sea level, with nothing but a hodgepodge system of peat dams and concrete rubble to restrain the brackish delta waters. Overactive beavers, like the one on the Jones Tract, are the least of the problem.

Like everyone else in California, the engineers who watch over the delta's levee system are at the mercy of probability, breathing a sigh of relief every day that goes by without the catastrophic shaking of the Big One. "In any given year there's not a large chance of a huge earthquake," says **David Sunding,** chair of the Department of Agricultural and Resource Economics. "But those risks accumulate over time. And by the time you look two decades into the future, there's a two-thirds chance of a very large quake that will affect the delta's water system." Even an apparent bounty—consecutive years of high rainfall—poses risks. River flows would rise along with reservoir levels, placing added stress on levees so that even a minor structural failure could set off a chain reaction, flooding fields and devastating crops.

Inherent in either of these scenarios is the threat to drinking water. The delta houses the State Water Project, two massive pumps that send water to Southern California. If the levees are overtopped, the salt water of the bay will infiltrate the Sacramento and San Joaquin Rivers, rendering the supply undrinkable.

PHOTO: Edward Caldwell

Above: Professors and Delta Independent Science Board members Vincent Resh (right) and Richard Norgaard stand on a levee on Sherman Island along the Sacramento River.

"The worst-case scenario is three months without water," says Resh. "And that's from Fremont down. Silicon Valley, Los Angeles, everything."

Not Just a Human Problem

Of course, farmers and thirsty urbanites aren't the only ones who need water. According to ESPM associate professor **Stephanie Carlson,** "many of California's native fishes are declining, and the causes are rooted in habitat loss and the introduction of non-native fishes into California's waterways." She emphasizes that our current multiyear drought may be the "nail in the coffin" for those populations already facing extinction.

Carlson's research focuses on understanding where and why fish populations are persisting. She found that several native fish, including commercially harvested salmon, live in "intermittent streams"—waterways that flow continuously in the wintertime but break into isolated pools during periods of low rainfall. As drought or human usage reduces stream flow, water quality deteriorates, resulting in higher temperatures and less oxygen. In pools that dry up completely, all fish die, of course, but some "refuge" pools persist through the summer—and these habitats do support fish.

Carlson's team has found that "the survival of imperiled salmon and trout varies among summers, but is highest after wet winters." Following wet winters, streams flow longer into the summer, more pools persist, and water quality is improved. But, interestingly, "almost regardless of winter rainfall, most fish mortality is concentrated in late summer," meaning that early, abundant fall rains may be as important as the previous winter's storms.

Carlson believes that these findings should guide management. Urban development in the Bay Area is spreading from flatlands to the hills. "We need to focus our conservation efforts in those upper headwater streams—many of which are intermittent," she says. Carlson also stresses that native fish have adapted to the seasonal shift from flowing streams to standing pools, while non-native fish have not—thus intermittent headwater streams may be important refuges for native fishes.

While diverting less water from streams during summer might help juvenile salmon, managing outcomes in the ocean is far more difficult. In 2007 and 2008, the West Coast Chinook salmon population collapsed, with the Sacramento River fall run reduced by 90 percent. Fisheries closed at a cost of millions of dollars, and the federal government declared a disaster. While the crisis was attributed to low ocean productivity beyond human control, human degradation of freshwater salmon habitats worsened the impact of poor ocean conditions.

Most salmon-breeding habitats in the Central Valley lie upstream of dams. Today, most Central Valley salmon are born in hatcheries; many circumnavigate the delta in trucks and are released

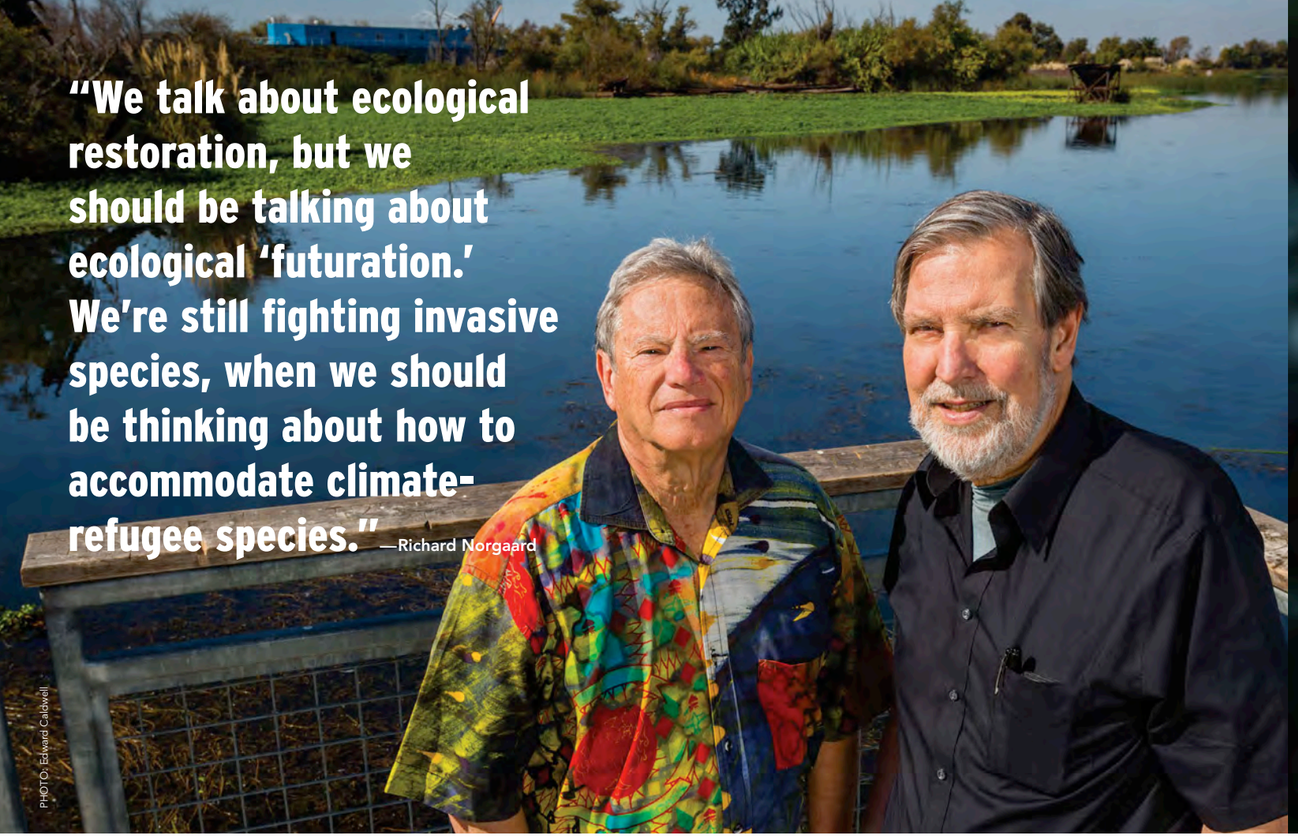


PHOTO: Edward Caldwell

PHOTO: Jim Block

into the San Francisco Bay. Because these fish don't swim through their natal rivers and the delta, they have no way to retrace their paths as adults. So they go everywhere, mingling with the broader gene pool. This "straying" erodes genetic differences among populations and increases the risk of collapse. It's possible that a more vibrant, genetically diverse salmon population could have better resisted the environmental disturbances of the mid-2000s. "It's like having a broad portfolio of financial investments, as we've been taught with our 401(k)s," Carlson says. "Maintaining multiple distinct populations with diverse traits and dynamics provides insurance against environmental change."

Tunnel Vision

There are some who see a potential solution to many of California's water problems in the form of the Twin Tunnels, a massive undertaking reminiscent of the muscular reclamation projects of yesteryear. The tunnels—30 feet across and 40 miles long—would divert massive amounts of Sacramento River water under and around the delta. Proponents of the project (formally known as the Bay Delta Conservation Plan) argue that the tunnels would reduce the effects of earthquakes and floods, offer protection for habitats and fisheries, and guard against saltwater incursions into the drinking supply, given the near inevitability of sea level rise. Opponents say that the environmental protections are inadequate, that the $15.5 billion price tag is too high, and that the project would simply legitimize and reinforce unsustainable agricultural practices.

"[The tunnels] are the best option I see out there for improving the system in terms of both water-supply reliability and environmental quality," says Sunding. "The current system isn't working. Not for fish and not for water users." But a project of this size is staggeringly complex: The initial environmental impact report ran to 22,000 pages and listed 750 potential impacts. And even with all that study, much disagreement remains. Some environmentalists worry about the effect on fish habitats, but others suggest that more tunnels in more places would offer greater opportunities to manage water flow around the needs of endangered species, such as the delta smelt.

Sunding is cautiously optimistic about the tunnels, based on work he's done to help the California Department of Water Resources model the economic ramifications of the project. "Ultimately, the benefits and the costs depend on what the operating criteria are and what the water deliveries are," he says. "But the cost-to-benefit ratio looks favorable."

PRESERVING THE INTEGRITY OF RESEARCH

"If you go back 10 years, everything was done as combat science," says Vincent Resh, a Delta Independent Science Board (DISB) member. "Everybody had their own expert, and nothing ever got resolved." "Delta science is conducted with about 100 different agencies," says Richard Norgaard, the board's first chair. "How do we get all that knowledge to come together and make rational decisions? Who has a brain 10 times the size of Einstein's to fit it all together?"

The 2009 Delta Reform Act changed the dynamics by forming the Delta Stewardship Council (DSC) and mandating that the DSC develop a Delta Plan. The DISB argued that the Delta Plan should have a Delta Science Plan which has now been developed under the leadership of the Delta Science Program staff and with the cooperation of the many agencies doing delta research.

"Things seem to be changing for the better," says Stephanie Fong, the acting science program manager for the State and Federal Contractors Water Agency. "The DISB represents the independence of the science necessary in a very political delta climate. Having a board that's separate from the various interest groups is absolutely invaluable."

Correcting Previous Corrections

Norgaard, on the other hand—also an economist with extensive experience in the delta—thinks that engineering solutions and financial analyses might engage the problem too narrowly. "We're now trying to correct the outcomes that were the unexpected consequences of all the corrections we made earlier," he says. "Change is happening. And the idea that we can keep restoring things to the way they were in the past, well, that's just not the nature of the world we're in anymore."

No matter what happens in the future, water is forever going to present as many problems as opportunities. There's always too little of it, too much of it, or just the right amount...but in all the wrong places. Still, while the Golden State seems to have more than its share of water woes, many potential solutions are well within sight. "Water doesn't have to be a limiting factor for California," says Sunding. "But it could be if we blow it."

BS 1983 CONSERVATION AND RESOURCE STUDIES
BS 1984 POLITICAL ECONOMY OF INDUSTRIAL SOCIETY

BILL&BARBARASTEELE

It's the sort of story most of us can only dream about: leaving behind the demands of a high-pressure career to pursue a new life as a farmer. It's what Bill and Barbara Steele did—and they've never looked back. In 2002, the couple was living in Marin County, where Bill worked as an equity research analyst and Barbara was the CFO of a manufacturing company. A few years earlier, Barbara had started doing pro bono work with organic farms and vineyards in the Capay Valley—and was bitten by the farming bug.

By Anne Canright | Photos by Bryan Mikota

"We had some pie-in-the-sky discussions: You know, if we ever did something, what kind of property we'd like," Bill explains. "We wanted something that was a blank canvas, where nobody else had made mistakes and we'd have to rip it all out. We knew from our organic-farming friends that we wanted something isolated, to avoid chemical drift from conventional farms. And then, of course, being from California, we knew we had to find good water rights."

On a visit to southern Oregon, Barbara finally got serious—and found what is now Cowhorn Vineyard and Garden, a 117-acre parcel bordered on two sides by Bureau of Land Management lands. The Steeles own the acres across the road to the river, and the nearest farming neighbor follows organic protocols.

"We weren't farmers," Bill says. "Neither of us had ever been on a tractor. So we started doing analysis—soil analysis, weather analysis—because our philosophy was, and still is, to let the land tell us what to grow, versus trying to impose our will onto it." The results of two years' worth of study determined where the roads should go, which in turn delineated blocks of land with different characteristics that are dedicated to individual crops.

When it came to deciding on wine varieties, analysis was also key. "I wasn't a farmer, but I am a math guy, and if you give me a set of numbers, I can make sense out of them." he says. "For example, growing degree days—it's a form of sunlight. [France's] northern Rhône region is somewhere around 2500 to 3000; Cowhorn is 2700. The analysis kept saying, Rhône, Rhône, Rhône, so we planted Rhône varietals."

A Biodynamic Philosophy

The growing principles that the Steeles follow are tenets of Biodynamic® agriculture. At its core, Bill explains, biodynamic agriculture involves three basic principles. "First, no synthetic chemicals anywhere on the property. Second, you can't monocrop—and so in our case we have cherries and asparagus and lavender and hazelnut trees, in addition to vines. And third, you try to minimize outside inputs in order to create a closed-loop system." One aspect of the third point is the use, in fermenting wines, of only indigenous yeasts that are found on-site, which helps give the Cowhorn wines special characteristics that have earned the winery top honors.

The biodynamic philosophy has its share of detractors for its championing of special "teas" and "potions." Bill, however, shrugs off the criticism, saying it's mainly a matter of preference. "Some of the things you read about are probably less than 5 percent of what we do. The vast majority is commonsense, boring farming. But if we do everything correctly, it boosts ripening a week to 10 days, and that's huge in the wine industry. It gives us a little bit more flavor, a little bit more color, and allows us to make, incrementally, a little bit better wine."

"We weren't farmers. Neither of us had ever been on a tractor."
—Bill Steele

The Steeles have 25 acres of grapes—just shy of 50,000 plants—which become fine syrahs, marsanne roussannes, and viogniers. The winery was built to produce between 4,000 and 4,500 cases, and that's where they want to keep it—at an artisanal level. They also sell 7,000 pounds of asparagus a year to three local markets in the Ashland area.

Building upon Sustainable Principles

And now that the farm is as under control as a farm ever can be, the Steeles have embarked on a new project: a tasting room that will be the biodynamic equivalent of a sustainable construction. "It's going to be one of the greenest buildings in the country," Bill explains. "It's consistent with the Cowhorn brand. But it's also consistent with Barb's and my philosophy. The energy efficiency will be through the roof; the water savings will be very, very high; the materials will all be sourced from sustainable products." Ultimately, they hope, it will receive Living Building Challenge certification. In addition, the Steeles are building themselves a small residence, after 10 years of living in 377 square feet above their offices.

In the process, Bill says, they are creating a local market for green building supplies. "I know from all the guys who are building for us that they've never built anything quite like this before. They're so jazzed to come to work, because they're learning something new. And now they'll have this knowledge to apply to other buildings. So in small ways, things will change. And that's part of what Barb and I are trying to do."

From the vineyard to the lab, Bill and Barbara Steele practice biodynamic techniques.

Q&A The Berkeley Food Institute

The executive director and three student fellows weigh in on their work and how food is a catalyst for change. By Anne Canright. Photos by Jim Block

Ann Thrupp

Post doctoral Fellow '90 Energy and Resources Group (ERG)
Executive Director, Berkeley Food Institute

What we do: The Berkeley Food Institute (BFI) is a relatively new entity on campus, less than three years old, bringing together people from multiple disciplines. Our mission is to support and catalyze the transformation of food systems and, in so doing, to promote diversity, justice, resilience, and health. We serve as an interdisciplinary hub, and we have 130 affiliated faculty and staff members from across the campus. One of the main things we're doing is linking research with policy making and practice. We're also involved in educational activities, including organizing public events on critical food-related topics, funding student fellowships on community engagement, and helping to develop a food systems minor.

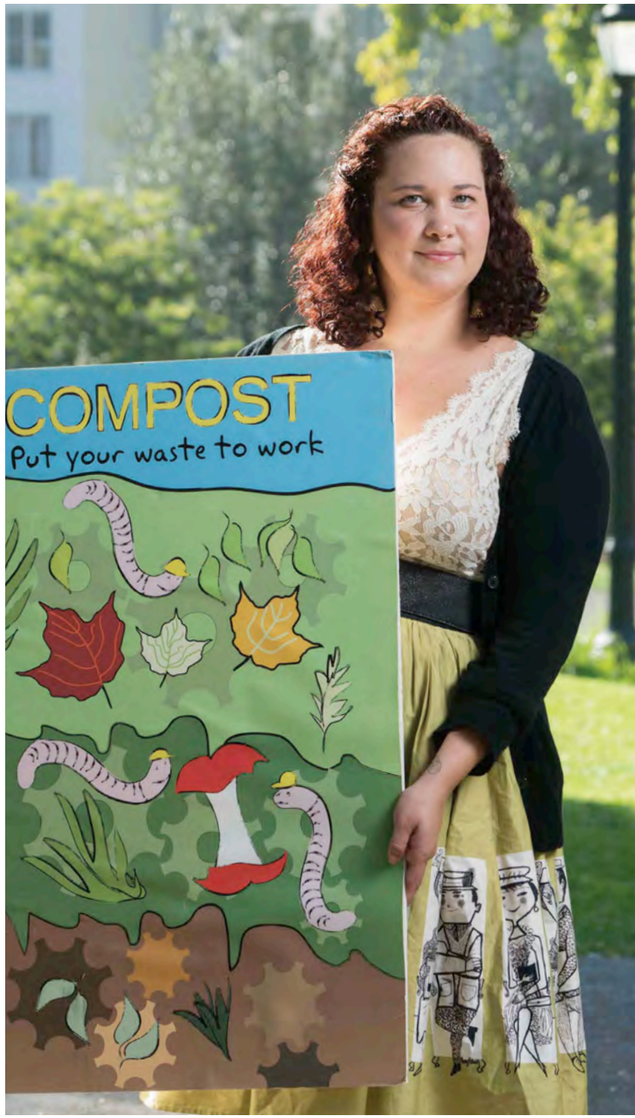
Berkeley Food Institute executive director Ann Thrupp considers student fellows a vital part of the institute's mission.

How we are different: One of the things that make us unique is that we're a partnership between the College of Natural Resources, the Goldman School of Public Policy, the School of Public Health, the Graduate School of Journalism, Berkeley Law, and the College of Environmental Design, among others. The BFI is raising awareness of the relevance of what researchers are doing and cultivating more interaction across sectors. Some of the people who are working together now on similar issues hadn't worked together before. We're helping to make those connections.

Real-world focus: The BFI aims to address practical problems and develop innovative solutions. As an example, a number of researchers are looking at the decline of bees and other pollinators and how to reverse that crisis for agriculture. We recently collaborated with the United Nations' Food and Agriculture Organization to create a policy report that was used by international decision-makers involved in protecting pollinators. As another, rather different example, last May we held a workshop on policies affecting federal food assistance. It brought together over a dozen speakers and panelists from federal and state agencies, NGOs, and academia—including the fields of public policy, law, and nutrition—to summarize needs and suggest potential ways to make healthy food more available, equitably, to recipients of food assistance.

Future directions: Our work spans a range of critical food system issues, from global to local. The term "food systems" refers not only to food production but also to distribution and consumption, as well as waste and impacts on health. We've recently identified a few major themes that we'll be focusing on more intently in the coming years: ensuring nutritious and affordable food for all; accelerating the adoption of sustainable agriculture; and fostering fair and healthy labor conditions. The main challenge will be sustaining funding, but we have a great start and great supporters. One important aspect of our work is student engagement—we've engaged more than 20 students, as project employees and as student fellows of the BFI. They're a vital part of our overall mission.

Right: For BFI fellow Laura Moreno, household food-waste prevention is a passionate focus.



Laura Moreno

BS '08 Conservation and Resource Studies; MA '15 ERG; first-year PhD student, ERG

How did you come to the BFI? While I was an undergrad in microbial biology, I started working for Campus Recycling and Refuse Services and found myself digging through trash and thinking about waste and recycling. After graduation I worked at the San Francisco regional office of the Environmental Protection Agency (EPA) for five years, looking at food waste specifically—compost and generating renewable energy from food. Ultimately, I started wondering how we can prevent food from being wasted in the first place. I decided to return to Cal to study consumer behavior: our interaction with food, socially and culturally. As part of my PhD work, I'm a community engagement fellow for the BFI, working with the Natural Resources Defense Council to look at household food-waste prevention. That partnership allows me to leverage my own research, which is very exciting.

Your research: I go to people's houses, and I interview them. I talk to them not just about food waste but about how they plan and shop for food, how they store their food, how they cook it, and then eventually how they waste it. I talk about people's relationship with food: mundane things like whether they over purchase and how much they waste, but also how they value food and what role it plays in their lives, in their family. I also look at how the larger industrial food system—technologies like the refrigerator, institutions like restaurants, grocery stores, and advertising—impacts how people relate to their food.

Big picture: When I worked at the EPA, I used to think that wasting food was this socially deviant behavior: Who would waste food? It's so valuable! Since then, I've come around to thinking that it's really people who *don't* waste food who are in the minority. Our entire system of industrial agriculture, of food delivery, of consumption, makes food waste almost inevitable. But that doesn't mean it's not solvable to some degree.

Thoughts about the future: I see the refrigerator as an important social actor in this. Many people find solace in a full refrigerator. So if we can design more efficient refrigerators, and make them shallower, so they appear fuller, that will be a huge step. Also, messaging is changing. The Ad Council will be launching a food-waste campaign in January that's oriented to consumers. I had the unique opportunity of talking with them as they were in development. This September, too, the EPA and the U.S. Department of Agriculture announced a goal to reduce food waste reaching landfills by 50 percent by 2030. So there's this perfect storm of more and more of the right people focusing on the issue.

Maywa Montenegro

Fourth-year PhD student, Environmental Science, Policy, and Management

How did you come to the BFI? I come from a background of molecular biology and journalism. I got my BA in biology at Williams College, then a master's in science writing at MIT, before joining *Seed* magazine in New York City. As an editor and reporter, I focused mainly on sustainable development, becoming increasingly interested in food and agriculture. At Berkeley, I've found a great community through the Center for Diversified Farming Systems, where I serve as communications coordinator. I'm also a student fellow of the BFI.

Your research: I work on the social science side of research in sustainable food systems—in particular, issues related to biodiversity in crops. In this context, diversity—which is both biological and cultural—depends on access to seed, rights to reproduce seed, and underpinning worldviews: whether genetic resources are considered private possessions or public goods, intellectual property or knowledge heritage, commodities or commons. I do a lot of history and document analysis, trying to unpack the production of knowledge using the critical tools of political ecology; human geography; and science, technology, and society studies, or STS. My last project was looking at crop wild relatives—species that are closely related to our domesticated crops but aren't cultivated. There's a lot of interest now among plant breeders and biotech researchers in using the DNA of wild relatives, because of their hardiness in the face of climate change.

BFI fellow Maywa Montenegro sees new meaning in the term "political science."

Big picture: I'm fascinated by an agro-ecological complex-systems approach. And seeds are the very foundation of that: They're what grows into the crop, they're what grows into the food we eat. They are an elemental commodity form—we buy and sell seeds, crops, and food. They all have a market value. Seeds also interconnect with myriad other industries—chemical, pharmaceutical, and biotech, to name a few. As other researchers have argued, when you control the seed, you begin to control many elements of the broader food system.

Thoughts about the future: We're met now with a profound challenge to think systemically. To understand that climate change, for example, is deeply enmeshed in a political economy underwritten by fossil fuels and premised on endless (and highly inequitable) accumulation. That food and agriculture crises are not separate from climate crises, or from many of the seemingly unconnected events of the day, such as human migration out of the Middle East; austerity and structural adjustment in Europe; worldwide struggles over land rights; free-trade agreements; and institutions that propagate race, class, and gender inequity. Our tendency to treat science as separate from politics and political economy has been a major impediment to progress on these interconnected social and ecological fronts. Many scientists hesitate to get "too political," but this view obscures the fact that no science is value-free. All sciences reflect social and cultural influences. A more "political science," then, can improve the objectivity of science rather than conceal its imperfections.

Kate Kaplan

BS '15 Society and Environment

How did you come to the BFI? When I came to Berkeley, I got involved in the Berkeley Student Food Collective and then the Berkeley Student Organic Garden Association. Although I originally intended to study forestry, I realized that growing trees isn't much different from growing food—just a different time scale—and so I shifted my focus to sustainable food systems. The BFI was developing a food systems minor, and I was asked to serve as a second-generation student representative in that effort. And then I was very fortunate to receive a UC Global Food Initiative fellowship, which allowed me to work closely with the BFI in 2014–15. It seemed like a natural partnership.

For BFI fellow Kate Kaplan, it all began in the garden.

UC Global Food Initiative: Launched by UC President Janet Napolitano, the Global Food Initiative is a push to put the UC system on the map for food systems research. Each of the 10 campuses and Lawrence Berkeley National Laboratory has three fellows, each researching a different aspect of food systems in collaboration with other fellows. So I was researching experiential learning, which is very sociological and pedagogical. Some people were researching a single gene in corn that has to do with drought tolerance. Other people were working with farmers to create computer apps that give feedback on the efficiency of their irrigation practices. The best part of the program is that it's bringing all of the campuses together. I worked with researchers at UCLA, UC Santa Cruz, and UC Davis; each of us brought a different perspective based on our local environment, and that all got mixed together in our final report.

Current directions: Right now I'm working with sustainable coffee, which is a crop that a lot of people might not consider food, but it's one of the largest traded commodities. It impacts everything that has to do with agriculture. I'm also drawn to a lot of the environmental impacts that people don't really associate with food—packaging being an important one. So my company is working on 100 percent compostable packaging for our coffee. We hope to be launching in a few months. I expect to keep working in the food industry, though I'd like eventually to move over to the nonprofit side and work more directly with farmers.

Thoughts about the future: People think that we don't have enough food to feed everyone, but the fact is, there's plenty of food out there. It's just not being distributed in a way that helps people. So much food is being wasted. A lot of food is going to animal agriculture. I think there needs to be more of a focus on how we can rearrange the food system right now to make sure that everyone is receiving enough. We don't need to be tearing down more rainforests to make more farms. We need to be looking at increased productivity—not in terms of quantity but in terms of nutritious quality—and better distribution. I have high hopes that the Global Food Initiative will help push public perception in a correct direction. It's about activism.

HELPING AGRIBUSINESS TO BECOME MORE RESOURCEFUL

MA 1992 ENERGY RESOURCES GROUP, PHD 1997 ERG

REBECCA SHAW

Rebecca Shaw has been poised to save the world since she was a high school student in Monterey, California, learning to be a vegetarian. With the book *Diet for a Small Planet* and childhood Methodist teachings as her guides, she calculated that a future of eating meat—at least at the same rate that most Americans eat meat—was unsustainable.

By Tom Levy | Photo by Ian Martin

Today, as associate vice president and senior lead scientist at the Environmental Defense Fund, Shaw leads efforts to make food production as efficient, environmentally sustainable, and climate-change resilient as possible. That includes collaborating with such mega-companies as Walmart, Campbell's, Pepsi, and Smithfield Foods to develop agricultural supply chains that reduce greenhouse gas emissions—particularly through more judicious use of nitrogen-based fertilizers.

And she's tasted success.

In the past two years, she says, Walmart and its food suppliers have committed 25 million acres of croplands to a systematic program for reducing emissions of nitrous oxide, a major greenhouse gas, by reducing fertilizer use.

"If you can do that with nitrogen and greenhouse gas emissions reduction, you can do it with water, too," says Shaw. "You can use the power of the supply chain to push in the right direction for water sustainability."

Focusing on Water Sustainability

With California's snowpack at its lowest level in 500 years, it's easy to see why water sustainability, particularly in this state, is where Shaw is focusing her formidable energies. There's a lot of work to do to maintain the resilience of the state's water system and the $50 billion food business it irrigates, she says. To get the maximum value from the water at their disposal, farmers may have to fallow some land and plant more higher-value crops that are less thirsty.

But Shaw is also proud of the strides that have been made, including the 2009 passage of the landmark California Water Action Plan, the near-unanimous approval by state legislators of the Sustainable Groundwater Management Act in 2014, and last year's 31 percent reduction in the state's water use.

From Premed to the Amazon

Food and water resources were not always Shaw's main focus. As a premed student at Vanderbilt University, she once hoped to work toward a cure for cancer. But a summer class trip to Baja California sparked a deep interest in natural resources, so she moved back to California and earned a bachelor's degree in biology at UC Santa Barbara.

In 1989, she moved to Brazil and completed a yearlong stint as a research assistant, living aboard a raft on the Amazon River to analyze the water's nutrient dynamics. That was the year that world attention focused on the Amazon basin, which was dubbed the "lungs of the planet."

Fearing that their region's sovereignty was threatened, Amazonian political leaders encouraged urban newcomers to become tree-cutting rural settlers, Shaw recalls. She says that the state's governor even handed out chain saws. "That's where I learned

"I really love working at the intersection of climate change and systems and the environment—there's so much good work to do in that arena."

that it wasn't enough just to study what was going on; I really needed to dig in and better understand the causes," says Shaw, who had learned enough Portuguese to follow the political wrangling in state and city offices. "Once you get into the political and social issues creating what you're studying, that's where the real complexity and potential solutions can be found."

Systematic Connections

Witnessing Amazonian deforestation firsthand drove Shaw to return to school. She wanted to examine the political, social, and economic forces that propel decision-making about energy and natural-resource use. After scrutinizing all her options, Shaw chose the College of Natural Resources. "I loved Berkeley," she says. "My training always systematically connected what was going on across the globe with what was going on in California, helping us to see it all as an integrated system." She was especially influenced by **John Harte,** a physicist turned ecologist, and energy expert **John Holdren,** currently director of the White House's Office of Science and Technology Policy.

Now, pushing for water sustainability is just part of Shaw's effort to help agribusiness move from last century's extraction-and-consumption model toward a new emphasis on maximizing food production using as few natural resources—like water—as possible. "I have a very deep need to steward the planet in a way that is respectful of all beings, of all living things," says Shaw, who, along with her husband and 14-year-old son, tries to eat as low on the food chain as possible. "To keep this planet and this state as extraordinary for my son as it has been for the generations before me, it's not enough just to maintain the status quo and keep things from degrading," she says. "We must do things differently."

PHOTO: Adobe Stock

Rebecca Shaw spent a year living aboard a raft on the Amazon River.

PHOTO: Jim Block

For **Jimmy Dunn,** who will graduate with a BS in environmental sciences in 2016, giving back to the College of Natural Resources is an act of sustainability. “I received a call last summer asking me to donate to the Senior Gift Campaign,” he remembers. “I had to think about it for a long time—it was tough to consider making a gift when I have so many student loans to pay off.” But because he had been doing work-study in the College’s development office, he knew the importance of philanthropy—and that there was a Student Hardship Fund. “I’ve received a lot of financial aid,” he says, “so I figured it was not so much about me giving money back to the school, but rather taking a small part of my own financial aid and recycling it. It felt like a sustainable approach to giving.”

Since coming to Cal in 2012, Dunn hasn’t let the grass grow under his feet. As a freshman, he took a work-study position in CNR’s Office of College Relations, and he ended up staying for two years. He also worked as an undergraduate researcher at the Mills Lab and serves as chief of staff to ASUC senator **Wes Adrianson,** advising him on the development of six departments geared toward environmental justice and sustainable infrastructure on campus. He also went to work for The Green Initiative Fund (TGIF), where he currently serves as campaign lead. As of last spring, TGIF had distributed over $2 million to more than 140 student-initiated projects, including the Sustainable Algae Bioreactor, Soil Remediation Education, and Lawns to Meadows projects.

“Getting paid to work in environmentalism is super-important to me,” Dunn says. “As a self-supporting student, my finances come first, and I would have taken any job I could get. So I’m lucky that I get paid for the kind of work that really interests me.”

When it came to choosing a field of study, “I knew I wanted to do environmental work, but there were about 10 different majors in that field, and I felt overwhelmed,” he says. At first the interdisciplinary aspect of the environmental sciences major meant “lots of big lecture classes across campus.” But once Dunn began taking courses such as Energy and Society, his enthusiasm for the field took off. He’ll complete his thesis, “U.S. Subnational Ecological Footprints,” in May 2016.

Before he even walks across the stage to receive his diploma, however, Dunn is well aware of the importance of giving back to the College of Natural Resources, particularly to the Student Hardship Fund. “Undergrads can show that they’re already invested in the future of higher education,” Dunn says. “We need to ensure that the Berkeley experience is available to students of all socioeconomic backgrounds.”

— KIRSTEN MICKELWAIT

STUDENT GIVING IS ON THE RISE

For the past few years, UC Berkeley, in collaboration with CNR, has been conducting a Senior Gift Campaign, inspired by the success of such campaigns at private peer institutions. You’ll see from the following numbers that student philanthropy is catching on. With overall alumni giving at 12 percent, our seniors are raising the bar!

2013 – **21%** of graduating class 2014 – **25%** of graduating class 2015 – **30%** of graduating class

Iconic Buckeye | Photo by Jim Block

This California buckeye (*Aesculus californica*), located in Faculty Glade, is perhaps the best-loved tree on campus. Planted in 1882, it’s seemingly deadened from the inside out but continues to bloom every spring.

The buckeye is one of 16 distinctive campus trees featured on the “Tall Tree Tales of Cal” audio tour, launched last spring and available for smartphones via the Point app by Canogle, free at the Apple and Android app stores. We promoted the Tall Tree Tales tour in connection with our “Think Bigger” platform for Cal’s Big Give campaign in November, raising $156,137 for CNR.