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UtahState
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Photo: Gary Neuenswander

Utah State University has a long history of soil and water research. Some of the very first research conducted at the Utah Agricultural Experiment Station involved studies of irrigation, and today our faculty members are considered among some of the strongest in these fields of research. For example, Dr. Kelly Kopp has been named chair of the Alliance for Water Efficiency which brings together scientists, industry professionals and policy makers to advocate for wise water use throughout North America. In addition, Drs. Robert Gillies and Joanna Endter-Wada were recently appointed to the Governor's Clean Air Action Team and Water Strategy Advisory Team.

Utahns live in the second driest state in the country, and interestingly, it has been projected that Utah uses as much as five-billion gallons of water each day! With the ever-growing population in Utah, as well as the surrounding western states, it will be increasingly important to strengthen our commitment to efficient and thoughtful water use as demand increases for this critical resource in community and agricultural applications.

This issue of Utah Science highlights just a few examples of the important soil and water research that is being conducted by Utah Agricultural Experiment Station scientists. True to Utah State University's land-grant mission, the results of this cutting-edge research are integrated into our academic programs and, through Extension programs, transferred to communities throughout the state as we equip people with the most up-to-date, research-based information. It is critical for Utah State University to expand its research portfolio in these very important areas so that we can continue to play a valuable role in discovering solutions to the complex problems associated with managing limited resources. As we improve the quality and use of the land and water, we expand the capacity to support high quality food production and sustain human well-being.

As the new director of the Utah Agricultural Experiment Station, it is with great pride that I invite you to learn about the important water and soil research being conducted here at Utah State University. It is our commitment to remain Utah's most important source of research-based information in these critical areas as we move into a demanding and promising future.

Ken White

Director, Utah Agricultural Experiment Station

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UtahState University

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Photo: Gary Neuenswander

People in the Water Planning Picture

A sociologist walks into a meeting of hydrologists and water engineers...It's not the beginning of a joke.

Water is no joking matter, especially in the western United States. But water policy, irrigation engineering, climate science, water conservation and water quality are not topics that typically attract social scientists. Douglas Jackson-Smith, Utah Agricultural Experiment Station researcher and Utah State University professor of sociology, thinks it's exactly where sociologists should be focused because it's impossible to understand that state's water supply or model its future without measures of human behavior in the equation.

"People have always impacted how water moves around the landscape, but our ability to understand our water system with humans as part of the story is not as good as it needs to be," Jackson-Smith said. "One of our big questions is how different human settlement patterns affect water use and water quality."

Jackson-Smith's recent UAES project examined impacts of population growth and residential development on agriculture in the Intermountain West, a region that has experienced more than double the national average population growth since 2000. Jackson-Smith and his research assistants studied the effects of various settlement patterns on agricultural trends. They found that in rural areas, new housing developments that cluster homes and their attendant services like roads, power, sewer and water result in less lost farmland. Moreover, they found a 2% drop in farm sales linked to every 10% increase in the percent of a county's population growth that located outside urban boundaries. They concluded that local land use ordinances that guide patterns of housing growth can have profound impacts on the viability of commercial agriculture.

Because they needed detailed information about the location of housing, their project discovered that much of the available remote sensing data in the western region misses many homes that are not part of high-density developments. Yet these types of scattered large-lot home sites can have serious impacts on local farmers, especially in the Intermountain West.

"In Cache Valley, we know of many examples of new houses located outside incorporated areas that don't show up in the data sets being used by many national researchers to classify urbanization and land

Douglas Jackson-Smith looks over one of the many canals that carry secondary water through parts of Logan. Originally designed to support agriculture, water systems in Utah are increasingly relied upon to do things they were not designed to do.

use," Jackson-Smith said. "We're working to find alternate sources of data that can tell us more about the spatial patterns of rural and exurban home development in places like Cache Valley. Only then can we understand the consequences of development that is widely dispersed versus clustered near existing city boundaries or services."

Among the services housing developments and farms in Utah need is water. Jackson-Smith's current UAES project is

focused on understanding how water use changes when areas transition from agricultural to recreational, exurban and suburban housing patterns. While much is known about the water use habits of highly urban populations in the west, few have studied how water use changes as agriculture transitions to more residential land uses. His project is exploring patterns of water use associated with different density and forms of residential development in formerly agricultural areas — including hobby farms, ranchettes, rural nonfarm residences, and new small subdivisions located on the urban fringe.

Jackson-Smith is part of an interdisciplinary team of researchers from several of the state's universities who work together on a major National Science Foundation-funded project called innovative Urban Transitions and Aridregion Hydro-sustainability (iUTAH). Their work is designed to gather systematic scientific information about how the water system is changing in the rapidly urbanizing Wasatch Range Metropolitan Area (a 10-county area in Northern Utah). The team is conducting social, engineering and biophysical science research to better understand how urbanization changes how water is conveyed, used, conserved and managed in this region, and the implications of water management for future water supplies and water quality.

Photo: Gary Neuenswander

The team is conducting social, engineering, and biophysical science research to better understand how urbanization changes how

Water

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There are several facts that make water research in Utah especially compelling. It's difficult to rate one water concern as more important than another — especially because water operates in a complex and interconnected system — but near the top is the fact that while Utah is the second driest state in the nation, Utahns currently use the second-greatest amount of water in the country per person per day. Looking down the road, population is expected to double by 2050, yet we're projected to receive more precipitation in the form of rain rather than as snow, which will place strains on our ability to rely on snowmelt as the source of irrigation and drinking water. The iUTAH project hopes to provide science-based information to decision makers who will be asked to shape Utah's response to these coming challenges.

Among the least studied, but critically important components of Utah's changing water picture are systems managed by cities (that provide most public culinary water to our residents) and the many irrigation and canal companies that continue to supply water not only to agriculture, but also to thousands of residential users. "A lot of people who study water have focused on individuals and how we use water in our homes, or they study big water policy issues like Colorado River agreements that come into play when the federal government is involved and water crosses state lines," Jackson-Smith said. "Those are not unimportant to our water future, but there is a middle scale of water actors, including city public water utilities and irrigation companies, whose actions are not well understood, yet who make what I think are some of the most important decisions about water in Utah."

He believes that is especially true in areas that are currently transitioning from rural, agricultural use to more urban uses — areas where there is a history of crop irri-

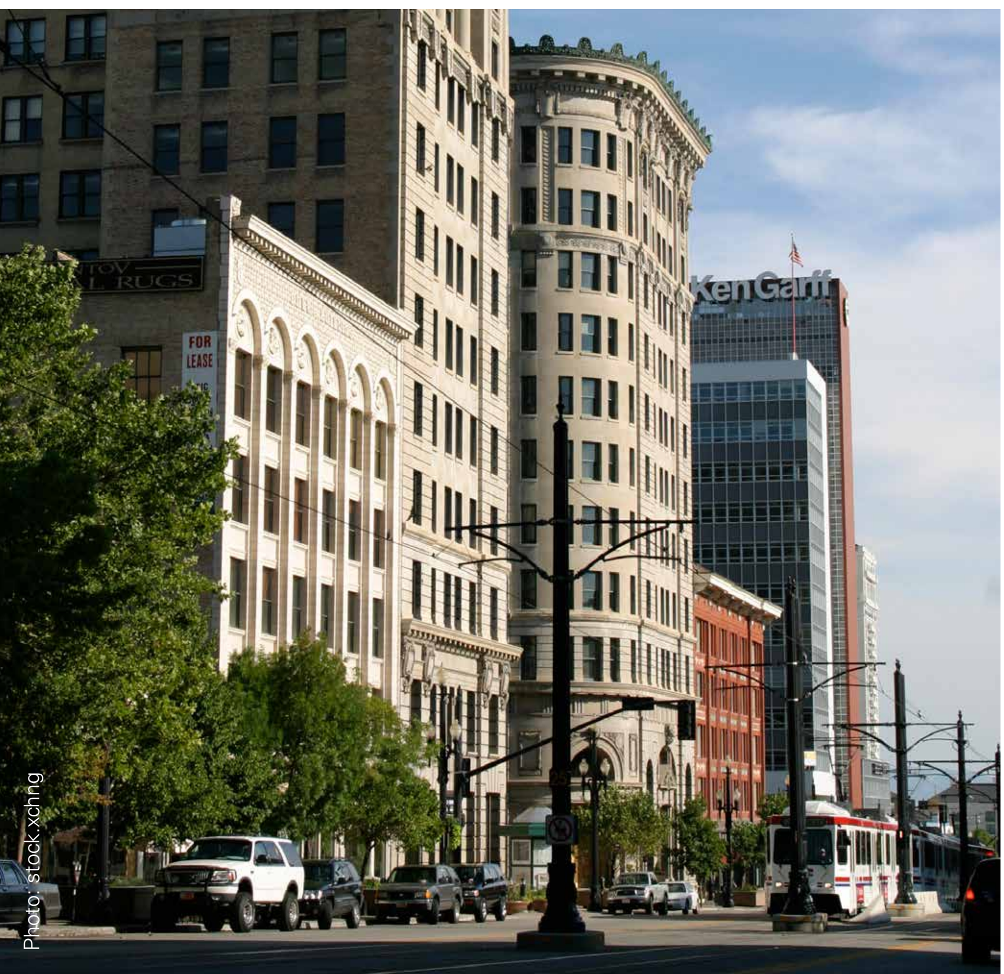

Photo: stock.xchng

Downtown Salt Lake City.

gation and the older canal infrastructure is not yet gone. Jackson-Smith explained that in Logan City alone (which is home to Utah State University) an estimated 12 irrigation companies still supply secondary water to residents who have water shares, all in the same areas that the city supplies culinary (potable) water. Similar arrangements exist in other parts of Utah where hundreds of independent water suppliers each manage parts of the water system.

The problem is that all water is part of a larger, interconnected system and managing it in pieces with little coordination is not likely to be sustainable, Jackson-Smith said. In many cases, they are finding that there are not even good maps of irrigation companies' infrastructure charting things like canals, gates and directions of flow. People who have individual water shares may know how their part of the system works, but Jackson-Smith speculates that company water masters are probably the only ones who understand their system as a whole and how it must be balanced in order to function effectively.

"Not all of the water we see running down gutters here in the summer is there because people are watering their lawns too much," he said. "That is part of the canal system as the city of Logan was built around it."

Similarly, city utility managers understand the parts of the water system that they control. When city and irrigation company infrastructures overlap, however, there are rarely any people who are tracking the interactions between these two systems. Jackson-Smith and his colleagues are focused on getting a better picture of how these companies and their infrastructures work, but it's a task that takes time and requires building trust.

Jackson-Smith notes that Utah's existing water supply system was designed to support life-sustaining agriculture in the state's early years, and has evolved slowly to support growing industry and urban populations. However, the system is often being asked to do things it was not designed to do. For example, rapid transitions from agriculture to residential and commercial land use take place in an environment that is constrained by traditional water management organizations, existing infrastructure and legal arrangements that are not well equipped to facilitate transfers of water rights to new types of users. While the state's projections for future water use include transfers of some water from agricultural to urban use, it is a relatively small percentage of the planned future water supply for urban customers and this raises challenges for meeting the needs of a population of 5 or 6 million people.

"Water use is a sensitive subject anywhere in the west because water is critical to social and economic viability, yet gathering information about how water is used in transitioning landscapes is a critical piece of science that should guide decision making," Jackson-Smith said. "When you study this topic, some worry that it is just an effort to get people in agriculture to give up their water. As someone whose career has been spent studying and working with farmers, I can honestly say that this is not why I'm doing this research. I do think we are missing opportunities to develop innovative co-managed systems that take advantage of separate secondary and culinary water systems, and that provide opportunities for traditional water rights holders, who are mostly farmers, to receive economic compensation or benefits when more of their water is used by people not actively engaged in commercial farming."

This spring, the research team is preparing to do a survey of household water use attitudes, decision-making and behavior across a wide range of neighborhoods in Northern Utah — from the most highly urban areas of Salt Lake City, to the new subdivisions along the I-15 corridor, to the smaller city and transitioning rural areas in places like Cache Valley. They plan to explore how attitudes, values, socioeconomic status and awareness of local water infrastructure and policies vary across different neighborhoods. They also want to see how these factors shape landscaping preferences and water use patterns. One key topic will be to assess the degree to which social norms in neighborhoods lead to a high degree of conformity in landscaping and water use among residents. For example, if the neighborhood is dominated by classic irrigated turfgrass, a tree and a small border of plants, what happens when someone instead plants water-wise plants and small areas of turf or cuts the water and allows their lawn to go dormant when the weather turns hot — are they considered a trendsetter or an outcast, and do they expect to be able to continue these practices?

Jackson-Smith and his colleagues want to understand the social underpinnings of why people use water in the ways they do so that educational efforts and policies can be tailored to successfully encourage conservation and water quality stewardship. It's a complicated question, but answering is vital to Utah's future. – LH

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DESIGNING WHERE THE WATER GOES

What happens to stormwater once it hits the ground is one of the many things in nature that gets little lasting attention from most people. Architects and city engineers have to think about stormwater and plan for it, but most of us don't get very interested until it's raining unusually hard or when our homes are in danger of flooding.

Bo Yang, Utah Agricultural Experiment Station researcher and assistant professor in the Department of Landscape Architecture and Environmental Planning at Utah State University, and his colleagues are exceptions to that mindset.

Nearly every time it rains, more data are headed their way, and between storms they examine data, analyze stormwater samples and track temperatures. All of it helps them to understand what effects human activities have on the water between the parts of the water cycle that we learned in grade school: evaporation, condensation and precipitation.

When precipitation occurs, some water immediately joins surface water (streams, lakes, etc.), and some is taken up by plants that use what they need and release what they don't. Plants grow and animals rely on them for food and shelter. It seems like a simple system. Then people introduce hardscapes: rooftops, roads, sidewalks, patios and parking lots, all of which limit the amount of water that can get into the ground. To make things worse, all these impermeable surface areas change the

Photos: Gary Neuenswander

rate at which stormwater flows once it hits the ground.

"With the curb and gutter method we use here, water drops fall and are sent toward the gutter, down a drain, through a pipe and discharged into a river," Yang said. "Naturally, it would have been absorbed and filtered by the soil."

What the soil would have filtered, and still does in some places, are the metals and other chemicals that accumulate on all those hard surfaces until they are swept away by stormwater. Yang explained that although arid places like Utah have less stormwater to manage, it is important to do it well because pollutants build up between storms.

"When we don't have rain for a long time, dust builds up on the roads from traffic and bituminous materials and high levels of heavy metals like zinc, copper and lead are concentrated on the street," he said.

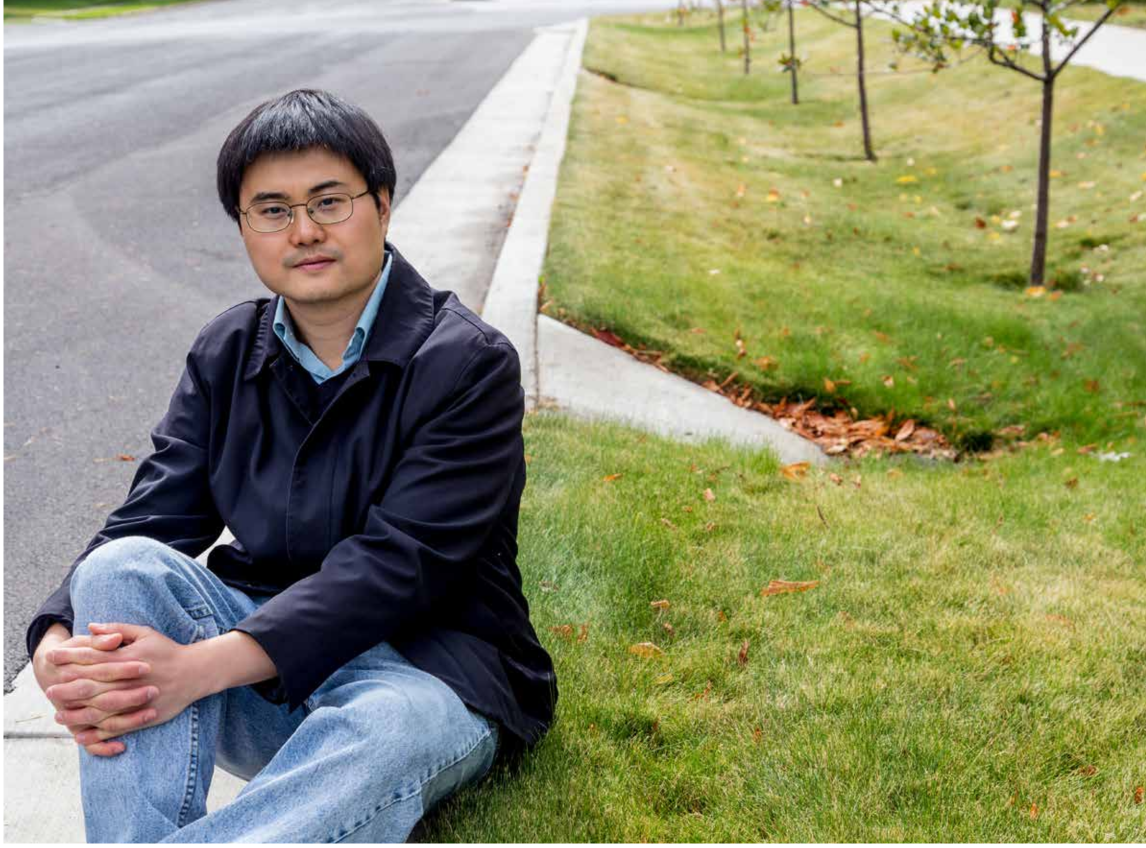
As part of a larger effort to understand an array of water issues in Utah, Yang and his colleagues have had instruments in place to capture water samples in two locations in the Salt Lake Valley and will soon be gathering samples in Logan as well.

One of the sampling sites is in the Daybreak development in South Jordan, a mixed-use community with some unusual features designed to enhance sustainability. For example: native and drought-tolerant plants cover at least 40% of each residential lot and 68% of common green spaces; man-made Oquirrh Lake retains stormwater and supplies supplemental irrigation water; 25 acres of constructed wetlands, canals and bioswales further aid stormwater handling without connections to piped, municipal systems.

In some parts of the development, curb and gutter construction causes stormwater to run off and be directed into the area's canals and basins. Other areas were built with bioswales adjacent to roads and walkways.

Bioswales are like wide, shallow ditches that slope gradually down to drain water away from paved surfaces and maximize the time water stays in the swale. They are typically planted with vegetation that further slows the water's flow. The combination of soil and plants' roots also creates a filtration system that removes many contaminants from the water before it reaches other parts of Daybreak's stormwater system and the larger watershed.

"In this sort of system, we are going back to using vegetation to clean the water, and using soils to filter and absorb pollutants," Yang said. "This is how landscape architects can have an impact on these kinds of problems, but everything comes back to cost efficiency. The dollar value of what nature can do for us here is worth quite a lot of money because when we use chemicals to treat water [that goes directly into a storm drain] it is much more expensive."



Landscape architect Bo Yang examines how community planning impacts stormwater quality and the long-term effectiveness of low impact development.

In addition to savings realized by putting cleaner water into aquifers without chemical treatments, using natural systems to handle the runoff pays in another way. Daybreak's developers shared figures detailing construction costs with the research team.

Because Daybreak handles all its own stormwater with its swales, canals, drains and lake, project engineers estimate savings of more than $70 million in stormwater infrastructure costs over the life of the project because of eliminated municipal impact fees and dramatic reductions in infrastructure normally required to convey water.

Yang's research group installed instruments that capture and store stormwater runoff in a series of 1-liter bottles. Once an inch of water has accumulated in that spot, a vegetated area adjacent to a road, a sensor triggers a pump to begin filling sample bottles. There is also constant data collection at the site, with instruments recording flow velocity, volume, precipitation and other factors. After a rainstorm, Yang, or a member of his research team, quickly retrieves the samples and replaces the bottles. The stormwater samples are chilled to maintain their integrity and tested at the Utah Water Research Laboratory at USU for contaminants, including metals, suspended solids, nitrogen and phosphorus.

Bioswales are like wide, shallow ditches that slope gradually down to drain water away from paved surfaces and maximize the time water stays in the swale. They are typically planted with vegetation that further slows the water's flow.

Another suite of instruments gathers stormwater samples and climate data at an elementary school playground inside the Daybreak community, which features impermeable blacktop and concrete. The difference in how water behaves at the two sites is immediately apparent and dramatically different.

"Ninety percent of the time when we get a big rain event we have minimal flow in the bioswale at Daybreak, but substantially more at the school site because water runs off the hardscape," Yang said. "The school has a detention basin and cobbles to handle runoff. But if there were a big flood, a hundred-year flood event, the whole playground and surrounding area is a detention basin. They have big capacity, but the bioswale slows water down and also improves water quality."

Yang has previous experience with bioswales and their concrete counterparts. His work as a graduate student in Texas included comparisons of ways to manage stormwater in The Woodlands development approximately 50 km north of Houston, a spot with a climate very different from Utah's. Houston receives an annual average rainfall of nearly 50 inches, while Salt Lake City gets just over 16 inches (at the Salt Lake International Airport weather station), plus 56 inches of snow — Utah snow that is famous for being dry and powdery. Because of Utah's low amounts of precipitation, little has been done here to study green infrastructure for stormwater.

Research assistant Pam Blackmore gathers water samples from the Daybreak site following a rainstorm.

Yang explained that although Utah gets less precipitation as rain than as snow, climate models predict more rain and less snow in the future: a change the state is not currently equipped to handle in terms of water storage or runoff management.

Yang's work is not all just a matter of hydrology and engineering though. People are an important part of the research and the success or failure of any landscape design. He is seeking to gauge people's perceptions of green infrastructure and their reactions to design elements like swales. In Texas, with its heavier rainfall, pooling water became an issue because of its potential to harbor breeding mosquitoes and also because children love to play in mud. The swales became a maintenance issue that people did not like, Yang said, so curb and gutter were used in a later phase of the development. Now when it rains there, the swales filter and slow the water in some spots while streets and homes in the newer neighborhoods are flooded.

Early in the study, Yang and his colleagues asked engineers and community residents to assess attitudes about swales, curbs and gutters and other design features and will continue to gather data about those groups' attitudes as the research progresses and opportunities arise to educate people about the usefulness of designs that may be new to them.

"Proving the performance of a design is key to acceptance," Yang said. "It's universal that people are resistant to change. They need time to think about it and to understand how it works."

Climate and population projections mean now is a good time to test methods that may help Utah better manage its stormwater and allow people to adjust to different landscape designs, because in the near future there will be more rain to manage and more of us to educate. – LH

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Bo Yang discusses a redesigned curb and gutter system that allows more stormwater to be filtered by plants and soil with research assistants Luigi Dragonetti and Sam England (left to right).

Photos: Gary Neuenswander

A SUSTAINABILITY MATTERS

AS THE MARKET FOR ORGANIC PRODUCTS CONTINUES TO SPREAD BEYOND THE PRODUCE ISLE INTO THE REALM OF POTATO CHIPS AND CLEANING SOLVENTS, IT SEEMS THAT MANY AMERICANS ARE BEGINNING TO WONDER IF TRADITIONAL INDUSTRIAL FARMING IS SUSTAINABLE.

But measuring what makes a farm sustainable or not — and understanding what sustainability means — is a complex process.

Jennifer Reeve, an associate professor of organic and sustainable agriculture at Utah State University, works with these experts to understand how ecological processes and cultural practices influence farm sustainability. Reeve, a soil scientist by training, studies the health and diversity of soils to help predict the long-term productivity of the land that provides food to people across the United States and beyond. Soil is just one aspect of agroecology — the study of all of the ecological and cultural processes that impact the health of a farm — but through their research, Reeve and her colleagues are learning what it takes to make a farm truly sustainable.

For most of human history, farmers have used what are now considered organic methods of farming, simply because there was no alternative. Although it is important to note that modern organic farming employs many techniques and technologies not available to early farmers and is not simply reverting to the ways of the past. Chemical inputs — fertilizers and pesticides — were first introduced in the early 19th century to skeptical growers.

"When scientists first came out with these new synthetic fertilizers, farmers and some scientists were concerned about what that would do to the health of the soil," Reeve said. "Despite these concerns, a drop in the price of fertilizers and pesticides in the mid-20th century changed farming dramatically."

Reeve explained that starting in the 1940s and 50s, farming became more industrialized and fertilizer and pesticide use dramatically increased. Though organic farming never really went away, "organic" as a movement took off in the 1960s as the public began to realize the side effects of synthetic chemical use in farming.

"There were some early scientists, but it was mostly farmers and consumers saying that they were worried about the direction that farming was going," Reeve said.

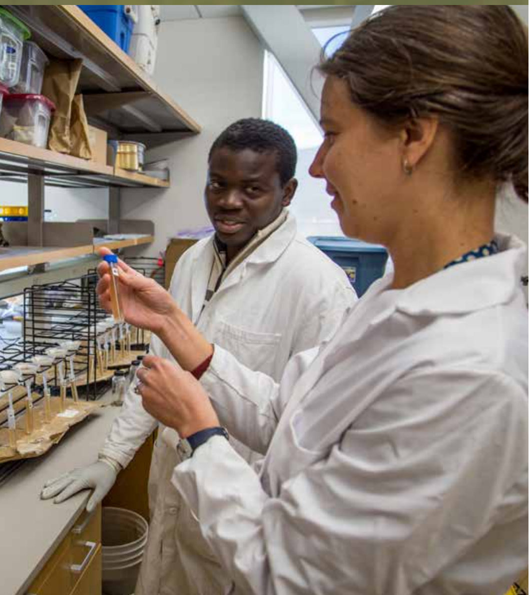
Reeve's work in agroecology does not necessarily promote the switch to organic farming, though she said many organic practices are more likely to improve the overall quality of the farming system. Instead, her research has shown that both organic and traditional farmers have room to improve their efforts to become sustainable.

"Sustainable is a word that is often confusing," said Reeve. "Some people will define sustainable agriculture as a specific practice such as organic farming, but that's not how scientists use the term. Instead, we try to define sustainability by specific criteria."

To be fully sustainable a farm must be productive, profitable, maintain or improve environmental quality, conserve natural resources and sustain local communities.

"If we're doing the first two at the expense of our soil and our water and depleting other resources such as fossil fuels, that's not sustainable in the long term," Reeve said. "Researchers measure a farm's use of natural resources such as oil, gas, fertilizers and pesticides as

> "INTEGRATED FARMING THAT TAKES THE PRAGMATIC APPROACH AND USES THE BEST OF ORGANIC AND THE BEST OF CONVENTIONAL OFTEN IS THE MOST SUSTAINABLE OPTION IN MANY RESPECTS."



use of natural resources such as oil, gas, fertilizers and pesticides as well as the system's impact on the surrounding environment to understand how sustainable the farming system is as a whole. Through these measurements, Reeve has discovered that many farms over rely on external inputs while depleting their natural resource base, all at the expense of soil and water quality. In those cases, how can you say that you're sustainable, even if you're productive and economically viable?

A lot of rural communities are dependent on farming, said Reeve. When you have larger and larger farms, fewer families farming, fewer businesses supporting those farms because those farms are only growing one or two crops, you have huge problems in terms of community function and that's happening across the U.S.

Community health is often overlooked when the question of sustainability arises, but Reeve believes that ultimately, farms must have positive effects in all five areas to be considered sustainable.

As a soil scientist, Reeve uses soil quality, the measure of the ability of the soil to support an ecosystem including human health, to understand the productivity of a farming system. On a large scale, problems with soil quality can be seen in erosion, where top soil that has taken thousands of years to form is lost.

"You can't just pick the soil up and put it back," Reeve said.

Erosion is a symptom of poor soil management and over reliance on tillage, but many intrinsic soil properties included in the concept of soil quality can also influence erosion. The amount of organic matter, nutrients, pH, beneficial microorganisms and pathogens, as well as the physical structure of the soil, all factor into Reeve's determination of the health of a farm's soil.

"If there's one thing that's really important as an indicator of soil quality, that would be soil organic matter — soil carbon," Reeve said.

Organic matter content can be a good measure because it influences so many aspects of soil quality. Microorganisms in the soil break organic matter down as they consume it, producing sticky substances that hold the soil together and prevent erosion. Organic matter also prevents the loss of soil nutrients though leaching.

"Leaching can be a big problem for water quality when you have all sorts of fertilizers and pesticides that are applied that then leach out of the soil into water ways," Reeve said. "Keeping the inputs where they are is important and having good soil quality with lots of organic matter helps do that."

Soil quality must be measured through comparisons because so many factors can influence the health of a farming system. Reeve works with a number of collaborators to conduct comparative systems experiments at various locations throughout Utah. One such experiment is located at the Utah Agricultural Experiment Station Kaysville Research Farm where she measures the effects of various input combinations on peach orchards. By looking at productivity, soil quality, pest pressure, biodiversity, water use and economics, over time, Reeve and her colleagues can determine the combinations of inputs, rotations and crops that promote the most sustainable farms.

Studying farms over time actually takes a very long time, as evidenced by some of Reeve's research in Snowville, Utah. In experiments started more than 15 years ago, USU researchers applied compost to replicated organic plots and measured wheat yield and soil fertility.

"They had over double the yield where they applied compost, but despite that it wasn't economical to apply," Reeve explained.

Soil scientist Jennifer Reeve and graduate student research assistant Mae Culumber discuss purifying soil DNA (top). Reeve and research technician Kareem Adeleke filter soil extracts to measure soil nutrients.

FIVE FACTORS DETERMINING FARM SUSTAINABILITY:

1. PRODUCTIVITY
2. PROFITABILITY
3. MAINTAINS OR IMPROVES ENVIRONMENTAL QUALITY
4. CONSERVES NATURAL RESOURCES
5. SUSTAINS LOCAL COMMUNITIES

When Reeve joined the faculty at USU, she decided to revisit the research plots and measure the productivity of the same soil — soil that hadn't had inputs added since the initial experiment.

"After 16 years, soil carbon was still double and yields were still double," Reeve said. "Nobody had really imagined that a composted organic matter would have such a long-lasting effect in the soil."

Making organic farming economically viable is sometimes a challenge, so research like Reeve's can make a difference to farmers who may be considering using organic practices on their farms. Organic farmers can't rely on the same inputs conventional farmers use, so they must build long-term soil fertility with targeted use of expensive inputs and a diverse cropping system.

Organic practices tend to promote better soil quality because farmers are more reliant on diverse crop rotations and use of organic matter like cover crops, compost and manure. However, Reeve explained, organic farming is not necessarily better when judged by all five measures of sustainability. Organic can be more expensive in many regions and organic farmers still use some of the same problematic practices as conventional farmers — such as leaving fields fallow and unprotected from erosion during an off-season. In fact, Reeve has found that a third kind of farming system may be the most sustainable overall.

Integrated farming that takes the pragmatic approach and uses the best of organic and the best of conventional methods often is the most sustainable option in many respects, Reeve said. Research has shown integrated farmers who increase the number of crops in a rotation can cut inputs like fertilizers by 85 percent, improving the overall soil health. Integrated farming is not bound by the all-or-nothing approach of conventional or organic farming systems which can make it more practical; yet, farms like these are not very common.

"In the economic model that we have, organic farms tend to be more economically viable than integrated farms because there can be costs associated with increasing the diversity of your system," Reeve said. "Customers know the word organic and they trust it. They don't know the word integrated. Integrated products can't necessarily get the premium prices that organic products can."

For now, a rapidly growing market for organic products is helping expand organic farming and research. Starting in the 1980s, sales in the organic industry really started to increase, Reeve said. The industry has been growing at double digits between 10 and 20 percent a year ever since then. Comparatively, the conventional food market grows between 2 and 5 percent a year. Reeve has also seen money for organic research increase during her years as a soil scientist, and students have a renewed interest in sustainable agriculture and local food.

"It's just really thrilling to see all of the enthusiastic young people who want to learn to garden," Reeve said.

Growing interest in sustainable farming may yet turn the tide toward integrated farming systems, as more traditional growers see the benefits of taking organic approaches to farming at least some of the time.

"It's difficult to change agriculture very quickly because it's livelihoods we're talking about and there's always a cost to learning new techniques," Reeve said.

Even so, she believes that continued growth in the organic sector will translate into more farmers going organic in the long run. It is also likely there will be a "spillover effect" of organic practices into conventional farming.

Reeve added, "While I suspect there will always be a market for certified organic produce, from a sustainability point of view, it makes a lot of sense for a grower to retain the flexibility of an integrated farming approach provided they can make it work economically." – ET

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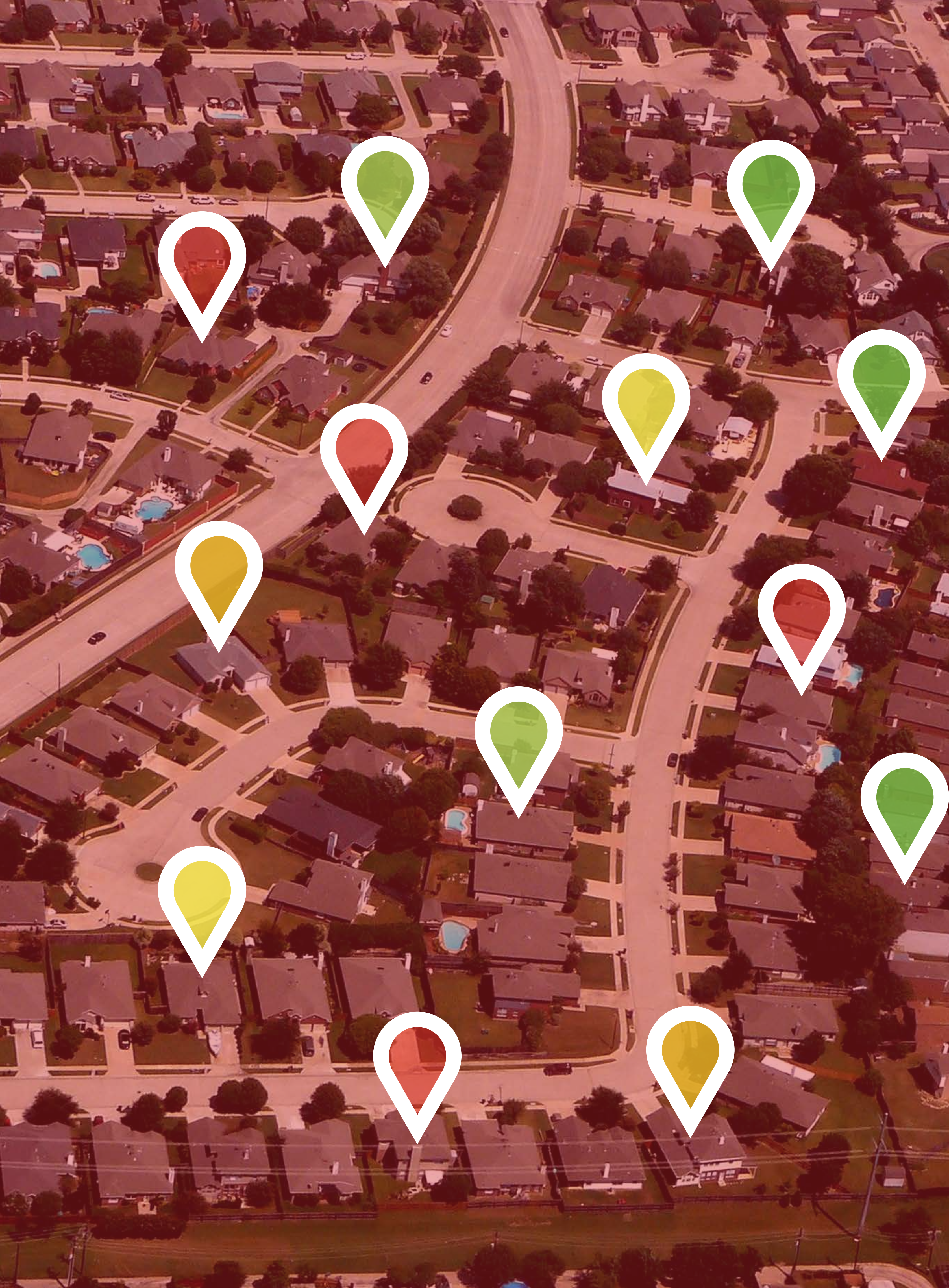

Images: Stock.xchng and Elizabeth Lord

PUTTING WATER USE ON THE MAP

Having enough water seems like a given for most people in the United States.

In modern times, even during drought, we turn on the faucet and get what we need — and then some.

In urban areas, landscape irrigation is sometimes curtailed by choice or by government edict during drought. Residents are told to water on certain days of the week or only early and late in the day. But unless you are watching streams run low, wetlands dry up or seeing crops stunted by lack of water, drought is more a word you hear on the news than a daily reality.

Utah is at the edge of the Great Basin, one of the world's great deserts, and the reality is that water is a scarce resource.

Joanna Endter-Wada, associate professor in Utah State University's Department of Environment and Society and director of the Urban Water Conservation Research Lab, and her colleagues are working to understand the region's water uses. Their research is guiding the creation and refinement of tools to help educate people about water use and, hopefully, to change behavior.

Endter-Wada and her colleagues Roger Kjelgren, professor in the Department of Plants, Soils and Climate, and Christopher Neale, professor in the Department of Civil and Environmental Engineering, have found that because water is so convenient and generally inexpensive, few people can tell you how much their water costs, how much they use or where it comes from. Water necessary to keep people alive is considered the highest priority and takes legal precedence in times of drought, Endter-Wada explained in a talk she gave at a 2013 USU-sponsored TED-X event (video available online: rgs.usu.edu/tedxusu/htm/tedx-usu-2013). People need water to drink, to produce food and for sanitation. But when water is cheap and seemingly plentiful, Endter-Wada said people do a lot of things with it that support their lifestyles, not just their lives. They water landscape plants that are not well-suited to arid climates, run sprinklers that water plants and adjacent concrete and asphalt, install pools and fountains and use water indoors without much thought.

Many cities in the west are looking to expand their water supplies to provide for

Sample Landscape Irrigation Ratio (LIR) Water Map

LIR less than one: Efficient
LIR between 1 and 2: Acceptable
LIR between 2 and 3: Inefficient
LIR greater than 3: Excessive

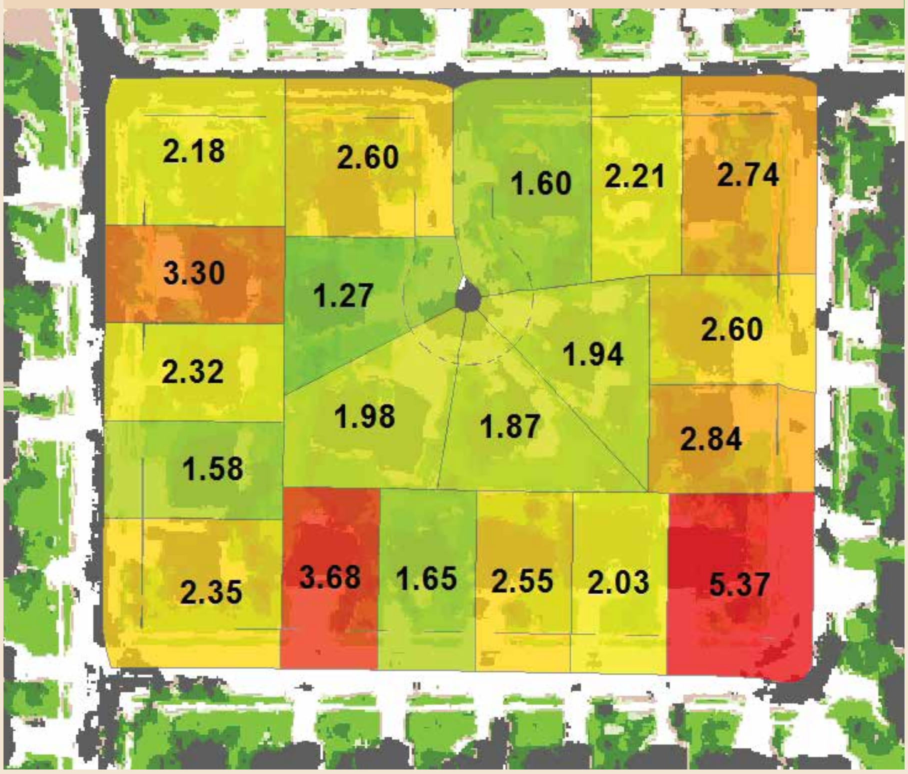

Image provided by: Joanna Endter-Wada

growing populations, but eventually cities must confront the fact that they are all pursuing the same limited resource. In urban areas, 50 to 70% of municipal water used by businesses and residences is for outdoor landscapes and general admonitions to conserve water are often, well, too general to be effective. That is especially true when people do not have an accurate idea of how much water they use or how much water their landscape needs.

Interdisciplinary research done by Endter-Wada, Kjelgren and Neale and their research team, found wide variations in the degree to which residents of some Utah neighborhoods efficiently watered their landscapes. Using a unique mix of plant science, remote sensing, mapping and social science, the research team created a tool that gives people a much clearer look at their water use and helps water managers effectively deliver conservation education. The tool they developed is Water Management Analysis and Planning Software, known as WaterMAPS™, and it does just what the name says: it creates maps that display which locations are conserving water and which are overwatering. The software integrates data from several sources, including plat maps, climate records, water billing records, aerial imagery showing the types of plants in a landscape (turfgrass, shrubs, trees, etc.) and known water needs of various plants. The resulting map shows water managers exactly which residents and businesses are overwatering landscapes and which ones are watering appropriately to meet water needs of their landscape plants. The idea is that if cities and other water providers can direct education outreach to specific over-irrigating water users, show them measures of their water use and clarify how much water the plants in their landscape need, people will be less likely to overwater.

The team's research turned up an unexpected finding. They discovered that the most significant factor in predicting whether residents or business owners were wasteful with water was whether they watered with hoses or used an automatic sprinkler system. Automated systems can be designed to water efficiently. However, most people use them primarily as labor-saving devices. Their conclusion: much about human behavior in conserving water comes down to convenience.

In a paper that appeared in the Journal of the American Water Resources Association JAWRA, Endter-Wada, Kjelgren, Neale and their co-authors Judith Kurtzman and Sean Keenan found that it is too convenient to let automated systems apply more water than a landscape actually requires. It takes time and effort to adjust watering times to account for different temperatures during the year, rainy days, etc., but people's tendency is to set the timer once and forget about it. Automated systems also make it possible for people to disconnect physically and mentally from their landscape. When people walk through a landscape and water it manually, they see when plants are stressed, when plants need water and when areas are too wet. Similarly, business owners often contract maintenance companies to care for their landscapes. While landscape contractors are onsite occasionally to mow grass or pull weeds, they are not there to override sprinkler timers after or during rainstorms or see broken sprinklers spew water onto streets.

In another paper that appeared in JAWRA, Endter-Wada and Kjelgren along with co-authors Douglas Kilgren and Paul Johnson reported on a 3-year study conducted with custodians who maintained public schools' landscapes. They again found that the type of irrigation system was important in determining water use, with automated systems facilitating the use of more water than was needed to maintain plants in healthy condition. But the knowledge, experience and commitment of the custodians were important factors in helping them to conserve water.

Endter-Wada also pointed out that residents of the arid west need to distinguish between their water needs and wants.

"Water needs and wants are increasing in the western U.S.," she said, "Because of a seemingly endless supply, people come to expect that water will continue to be available for all of their needs and wants. This expectation slowly transforms yesterday's water wants into tomorrow's water needs."

That sort of thinking is unsustainable. Endter-Wada said we must all learn that our choices about water have consequences. Sometimes they are easy to see, but often they are less visible.

"The best choices will not be easy choices," she said. "We can continue to pursue the current strategy of trying to stretch water to meet increasing uses, but ultimately water in the region is limited for all species. It won't be easy, but it will be best to face that reality sooner than later." – LH

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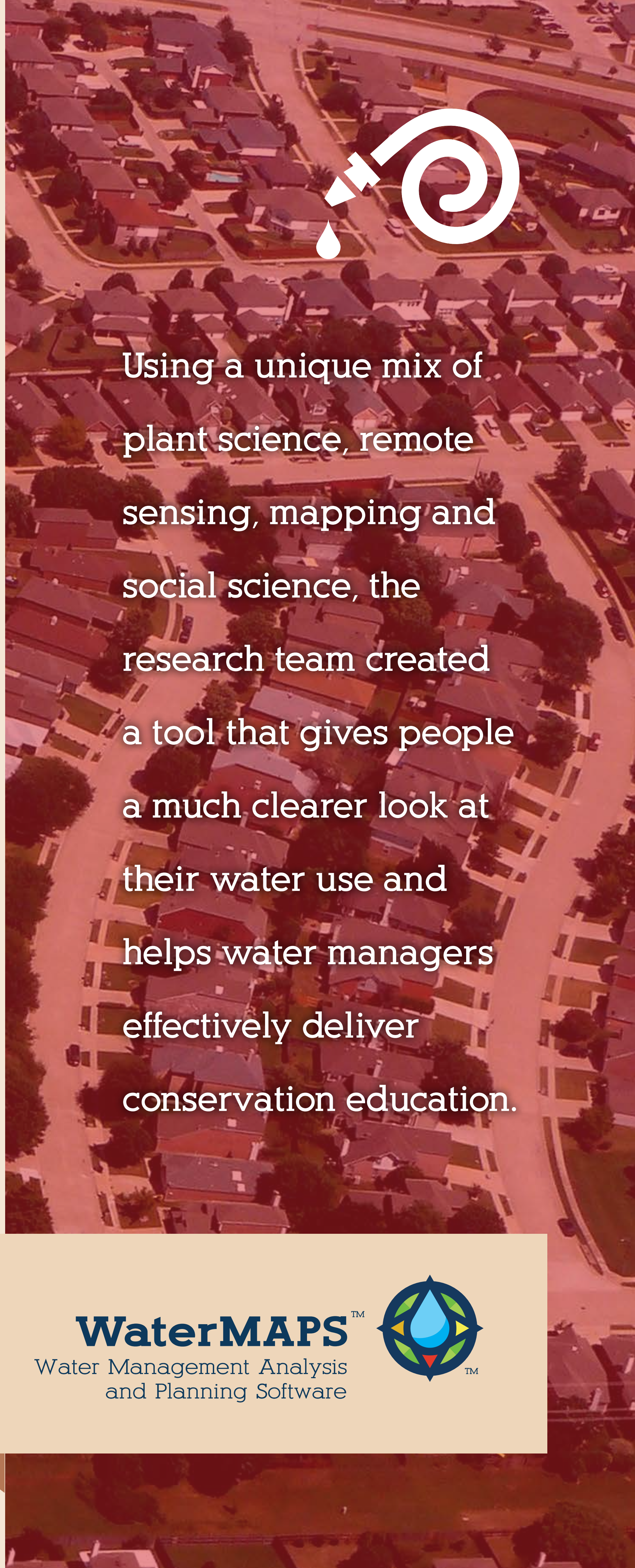
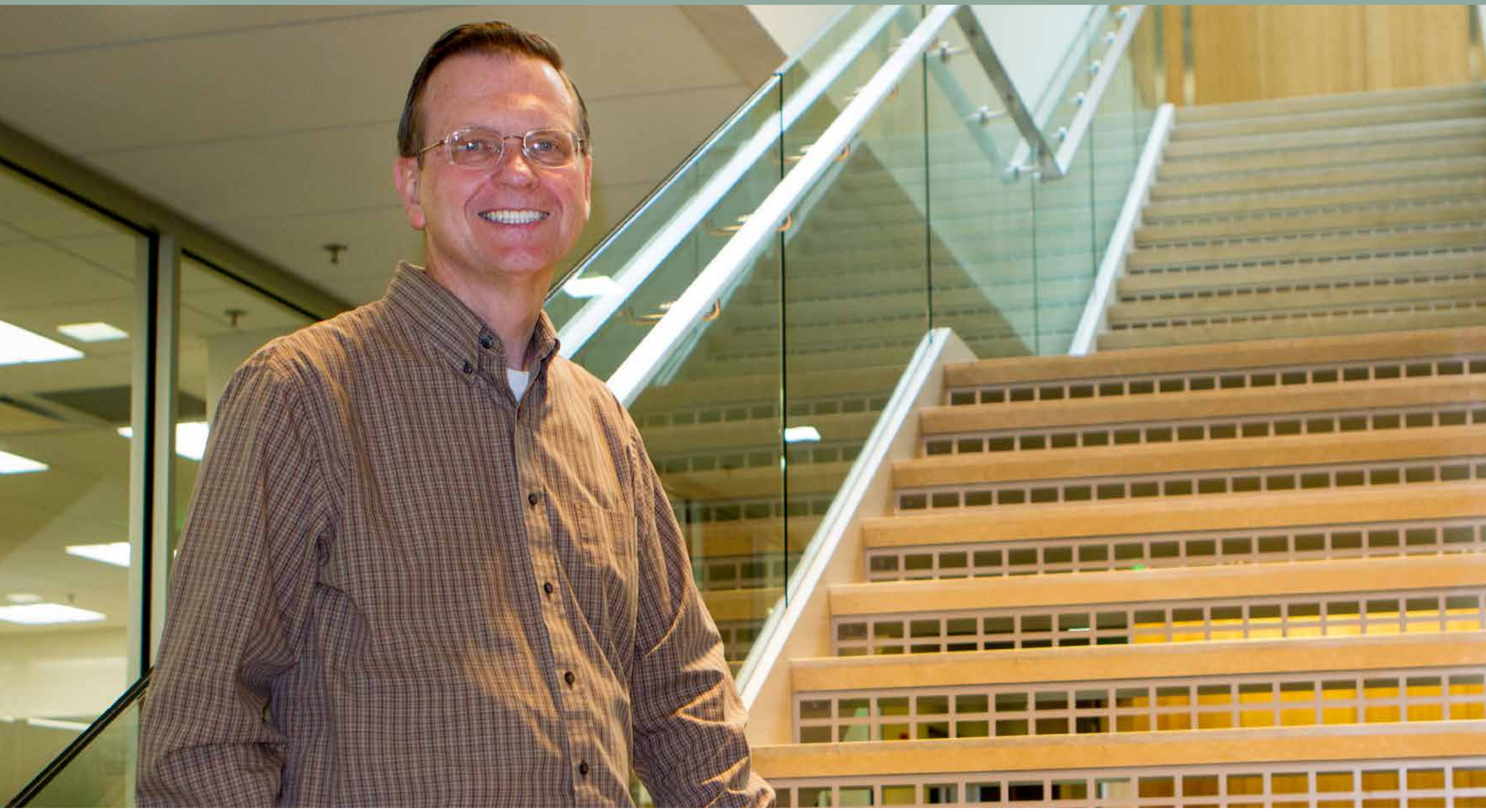


Using a unique mix of plant science, remote sensing, mapping and social science, the research team created a tool that gives people a much clearer look at their water use and helps water managers effectively deliver conservation education.

WaterMAPS™
Water Management Analysis and Planning Software

synthesis:



Deevon Bailey studies farm-to-fork traceability and consumer behavior.

Economist's Work is Journal's Most Cited

by McCarty

In academia, one measure of success is how often other researchers cite your work in their own books and articles as an example of reliable data on which they have based their own research.

DeeVon Bailey, professor in the USU Department of Applied Economics (APEC), and David L. Dickinson, a former faculty member in APEC who currently works at Appalachian State University, have been notified that their 2002 article, "Meat Traceability: Are U.S. Consumers Willing to Pay for It?", is the most frequently cited article published in the Journal of Agricultural and Resource Economics.

The article detailed what price consumers are willing to pay for meat that can easily be traced back to its origin. The research found that most consumers are willing to pay a higher price for meat if they know where it came from and how the animal was treated. Since that time the article has been cited more than 227 times.

"It's a nice feeling," Bailey said. "It says that your work has had impact, that people have recognized that it's an important piece of research. The fact that it was published over 10 years ago and continues to be cited frequently testifies to the quality and importance of that particular piece of research."

Science at Utah State

Photo: Gary Neuenswander

Hatfield

Bailey began publishing articles in the journal in the 1980s and since has had 11 published, the majority focusing on the cattle and beef market. Several of Bailey's more recent research projects deal with consumer willingness to pay for local retail products and the effectiveness of non-governmental organizations' interventions in the lives of small-scale farmers in developing countries.

Agricultural Experiment Station Farms to Benefit from Faculty Expertise

Utah State University professors Bruce Miller and Dillon Feuz have assumed new duties with the Utah Agricultural Experiment Station in addition to their current positions as heads of academic departments in the university's College of Agriculture and Applied Sciences.

Feuz and Miller's new assignments are oversight of operations and research on UAES farms. The experiment station maintains 11 farms that are primarily outdoor laboratories for a wide range of research conducted by USU faculty. In addition, some of the farmland produces feed for animals at the university's teaching and research facilities.

Miller oversees farm operations in collaboration with individual farm managers. His academic area of expertise is in agricultural systems and mechanization and he heads USU's School of Applied Sciences, Technology and Education. He joined the USU faculty in 1991 after earning his Ph.D. in agricultural education at Iowa State University. He earned bachelor's and master's degrees from the University of Nebraska. Miller is a member of the American Society of Agricultural and Biological Engineers and serves as a reviewer for the National Institutes of Health for National Institute of Occupational Safety and Health programs.

Feuz is head of the Department of Applied Economics. His new assignment is oversight of research conducted on UAES farms. Feuz received his Ph.D. in agricultural economics from Colorado State University and bachelor's and master's degrees in agribusiness from the University of Wyoming. Before coming to USU in 2006, Feuz was on the faculty of South Dakota State University teaching agricultural marketing and conducting research on livestock production and marketing. His career also took him to the University of Nebraska where his research focused on analyzing cattle management and marketing strategies. – LH

UAES Researchers Helping Shape Water & Air Policy

Three Utah Agricultural Experiment Station researchers have recently added new duties to their research and teaching roles that will shape water use and air quality policy in Utah and beyond. Robert Gillies, a professor in the Department of Plants, Soils and Climate (PSC), the state climatologist and director of the Utah Climate Center was appointed by Utah Governor Gary Herbert to the newly created Clean Air Action Team and the Water Strategy Advisory Team. Herbert also appointed Joanna Endter-Wada, associate professor in the Quinney College of Natural Resources and director of the Urban Water Conservation Research Lab, to the Water Strategy Team. Kelly Kopp, associate professor in PSC and the Center for Water-Efficient Landscaping, was selected for a term as chair of the Alliance for Water Efficiency.

The Clean Air Action Team (CAAT) includes 38 experts in areas including industry, healthcare, government and education, who will develop ways to address Utah's growing air pollution problem. Gillies expertise in climatology will contribute to the panel's academic team, examining ways poor air affects quality of life. He explained that the earth naturally gives off gasses, but in the winter those gasses get trapped in Utah valleys along with car exhaust and other particles and the surrounding mountains allow little mixing in the atmosphere.

"The result is an increase of tiny particles of solids or liquids that become suspended in the atmosphere, especially particles of pollution known as particulate matter 2.5 (particles 2.5 micrometers or smaller) that remain in the air," Gillies said. "These particles can get into people's bloodstreams and damage their health, potentially even taking five years off their lives."

The State Water Strategy Advisory Team is a 38-person team comprised of legal experts, water managers, conservation leaders, legislators, researchers and business representatives.

"We face far-reaching challenges in Utah's water future," Governor Herbert said. "From a growing population to drought concerns and funding problems, many complicated and weighty considerations demand we plan and prepare now."

The team will evaluate potential water management strategies, frame those options and their implications, solicit feedback and ultimately develop a 50-year water strategy for the state.

The Alliance for Water Efficiency (AWE), which Kopp will chair, is a non-profit organization which advocates for efficient and sustainable use of water throughout North America. The AWE provides information about products, practices and programs related to water use that is used by policy makers, fixture and appliance manufacturers, educators and the construction industry.

– LH

From top to bottom: Kelly Kopp, Robert Gillies, Joanna Endter-Wada

Cracking the Code of Nitrogen Fixation

by Mary-Ann Muffoletto

Utah State University scientists recently published two papers in a high profile academic journal that unlock mysteries of a chemical process upon which all life on earth depends.

In each paper, the researchers, under the leadership of USU biochemistry professor and Utah Agricultural Experiment Station Lance Seefeldt, describe newly discovered insights about nitrogen fixation, a process that converts life-sustaining nitrogen into a form that humans, animals and plants can access.

"It's an incredible irony," said Seefeldt, professor in USU's Department of Chemistry and Biochemistry. "Nitrogen, in the form of dinitrogen, makes up about 80 percent of the air we breathe. We need it to survive and we're swimming in a sea of it, yet we can't get to it."

Humans and animals consume nitrogen in the form of protein from food. Plants obtain nitrogen from the soil. Sounds simple, but it isn't. Nitrogen fixation is a complex and energy-intensive process. In papers published in the Sept. 23, 2013, online Early Edition of Proceedings of the National Academy of Sciences, Seefeldt and USU colleagues Edwin Antony, Zhi-Yong Yang, Simon Duval, Karamatullah Danyal, Sudipta Shaw, Anna Lytle, Nimesh Khadka, along with Dennis Dean of Virginia Tech and Dmitriy Lukoyanov and Brian Hoffman of Northwestern University, report research breakthroughs. Their research is supported by the National Institutes of Health.

"Dinitrogen consists of two nitrogen atoms joined by one of the strongest triple bonds known in chemistry," said Danyal, a doctoral candidate in Seefeldt's lab. "Breaking these bonds requires tremendous energy, which is released during a cycle of events associated with the transfer of metallic electrons and a chemical reaction called ATP hydrolysis."

USU researchers, as well as others in the science community, have studied steps of this cycle for decades. Yet the nature of the coupling between the electron transfer and ATP hydrolysis and the order in which each occurs has eluded them. Until now.

"With key experiments, we've demonstrated the electron transfer precedes ATP hydrolysis," said Antony, assistant professor in USU's Department of Chemistry and Biochemistry.

In the second paper, the research team describes the mechanism for hydrogen formation during nitrogen fixation.

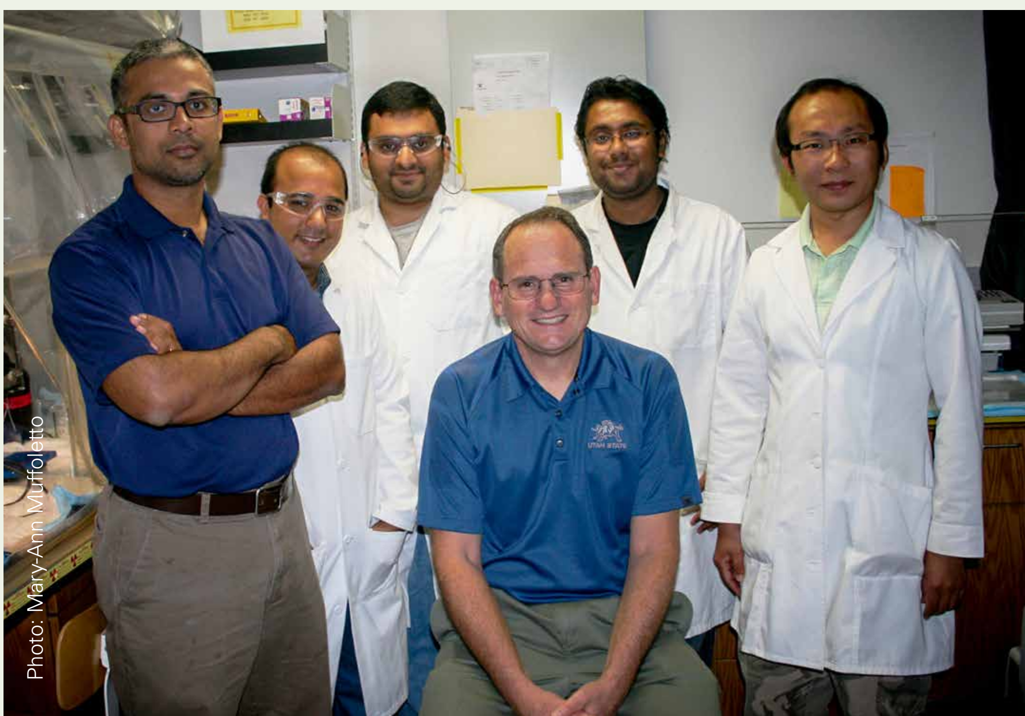
"This is a profound insight," said Yang, a doctoral candidate in Seefeldt's lab. "We previously predicted how this could happen, but now we've demonstrated how it happens."

The researchers' discoveries about nitrogen fixation could have energy-saving implications for the world's food supply.

"Two known processes break nitrogen bonds and allow conversion," Seefeldt said. "One is a natural, bacterial process. The other is the man-made Häber-Bosch process. The world's food supply currently depends equally on each of these."

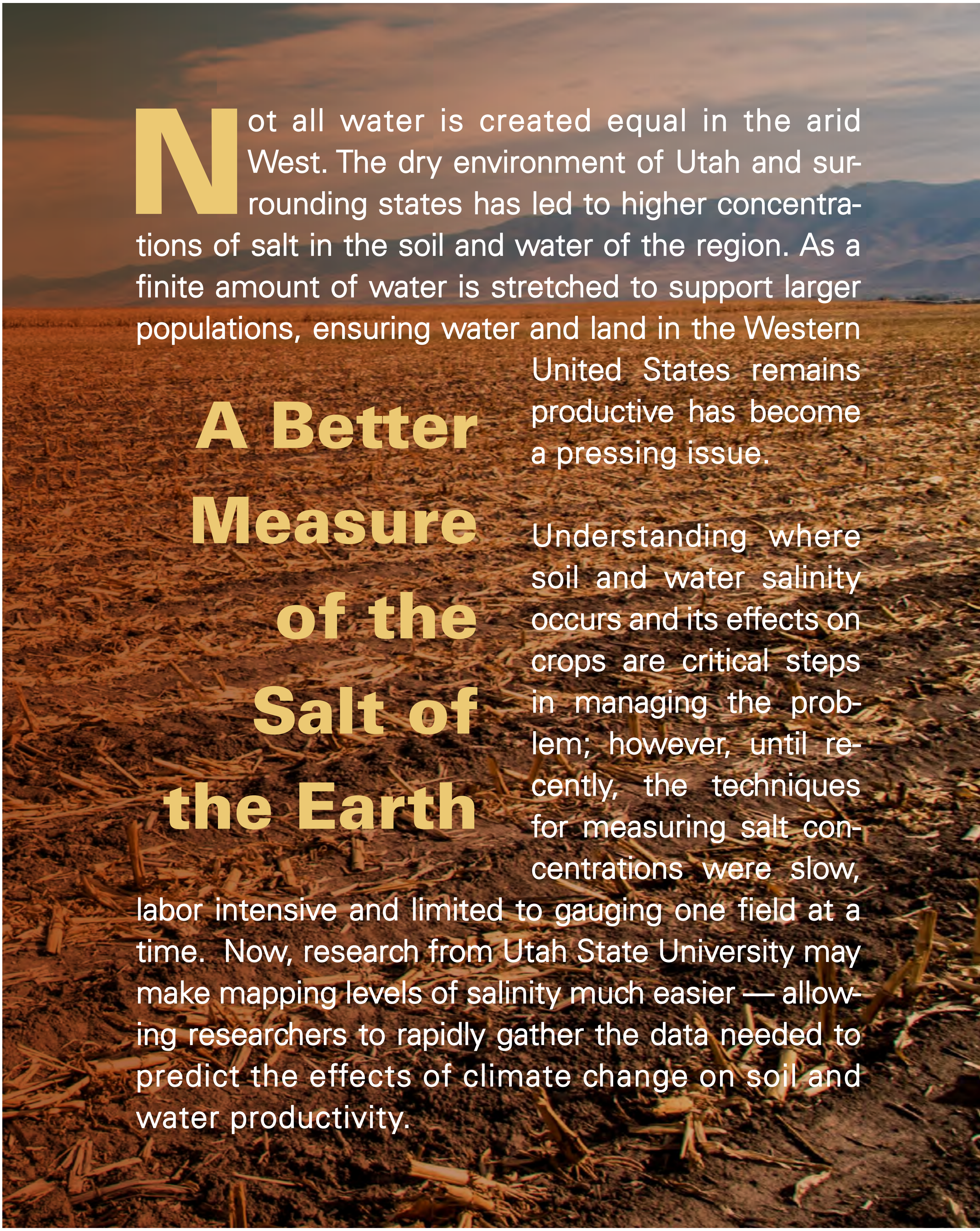
The century-old Häber-Bosch process, used to make agricultural fertilizers, is energy-intensive and depends heavily on fossil fuels, Seefeldt said, so interest is high in harnessing and making more use of the cleaner, natural process.

"By finally unlocking the conversion process, we can look to Mother Nature for answers," he said.



USU biochemists (from left) Edwin Antony, Nimesh Khadka, Karamatullah Danyal, Lance Seefeldt (seated), Sudipta Shaw and Zhi-Yong Yang are studying nitrogen fixation in Seefeldt's lab. Team members not pictured are Anna Lytle and Simon Duval.

Photos: Gary Neuenswander



A Better Measure of the Salt of the Earth

Not all water is created equal in the arid West. The dry environment of Utah and surrounding states has led to higher concentrations of salt in the soil and water of the region. As a finite amount of water is stretched to support larger populations, ensuring water and land in the Western United States remains productive has become a pressing issue.

Understanding where soil and water salinity occurs and its effects on crops are critical steps in managing the problem; however, until recently, the techniques for measuring salt concentrations were slow, labor intensive and limited to gauging one field at a time. Now, research from Utah State University may make mapping levels of salinity much easier — allowing researchers to rapidly gather the data needed to predict the effects of climate change on soil and water productivity.

Associate professor and Extension soil specialist Grant Cardon has spent his career working in the field of soil and water management. Since joining the faculty at Utah State University in 2005, Cardon has been involved in researching calibration techniques for making remote salinity measurements. Knowing current salinity levels is important for agricultural planning and for understanding the effects of climate change. Cardon and his fellow researchers hope to track and predict how changes in water policy and climate may influence the productivity of different river basins in the state.

"Whether we get more or less water… we needed to have some kind of baseline of assessment of what was there and how that would change if the water supply changed or if allocation routines changed," Cardon said.

Earlier techniques for measuring salinity were very labor intensive.

"Before these remote sensing techniques were available, you had physical, backbreaking work to take soil samples and determine their content in the lab," Cardon said.

More recently, remote sensing techniques have been developed to make measurements over larger areas. However, many of the techniques are only accurate within the region where they were developed. Salinity readings from remote sensors are influenced by many region-specific factors including clay and organic matter content and the type of salt found in a particular soil/water system. That makes developing a widely useful method difficult.

"What we're trying to do is tease apart what the influence is of each of those different conductive components," Cardon explained. "We try to focus in on what really is the salinity that matters to the plants that are growing."

In his work, Cardon uses electromagnetic induction meters to measure soil salinity.

"What they do is set up a potential for the movement of electricity, so you create a gradient and get conduction of electricity though the soil that completes the circuit," Cardon said. "When the flow of electricity is initiated, it creates a magnetic field around the circulation and the machine measures the strength of the magnetic field that's created."

The strength of the produced magnetic field is proportional to how the medium conducts electricity and can be calibrated to the salts, clays, organic material and other soil components that conduct electricity. Once researchers had properly calibrated the remote sensing instruments and understood what the measurements from the magnetic field represented, they were able to begin measuring salinity on a large-scale.

"Once we've got them well calibrated, we can go through fields quickly and map where the salinity occurs just by driving over the surface of the soil," Cardon said.

What makes Cardon and his students' approach unique isn't necessarily the machinery behind the measurements, but the math they use to understand how much each layer of the soil, measured by the remote sensing instrument, contributes to the total conductivity. This way, researchers can understand the degrees to which salt, clay and organic matter each contribute to soil salinity without extensive physical sampling and predetermine the depth distribution of the conductive components of the soil. This allows researchers to unify regional, wider-scale calibrations that get away from the need to extensively physically sample each field site used in the mapping effort.

In the West, soil and water salinity can change dramatically in the distance from a river's headwaters to its mouth as water travels downstream.

"Some of the water is used by plants but some of it's also being returned as runoff or return flows through the soils back into the river basin," Cardon said. "In an arid area, the further you get down a system with that happening, the more concentrated the salts become."

An increase in the concentration of salts occurs where the amount of water lost to evaporation is higher than the amount gained through precipitation, a process called evapoconcentration.

Evapoconcentration has many consequences, especially for growers downstream. Plants receive a majority of their hydration and nutrients through water

Soil scientist Grant Card measure soil salinity. Rese such as clay and organic adversely affects crops all

flow across the root membrane, and salts in the soil make this process more difficult.

"It limits water up-take and it can stunt the growth of the plants," Cardon said. Growers can be hit hard by the effects of evapoconcentration, which include a widespread decrease in crop productivity and growth.

The development of better remote sensing techniques has helped growers understand the quality of the soil they are farming. Working through USU Extension, Cardon helps farmers take this information and make changes to how they manage their land to minimize the effects of salinity and maximize productivity.

"We can teach them what kinds of plants they ought to be choosing for environments that have naturally high salinity," Cardon said.

Other techniques for managing soil salinity may seem counterintuitive. In some cases, the over irrigation of land can make the soil more salty. Saturating old lake sediments and shale deposits with excess water can draw salt out of the rock and into the water, amplifying the effects of evapoconcentration.

"If we can limit the flow of water through those sediments, we can greatly control the amount of salts in the lower reaches of the basin," Cardon explained.

In cases where changing irrigation and growing habits do not decrease soil salinity, Cardon and USU Extension may instead help growers remove salts from their soil. However, the process of washing salts from saline soils is not a permanent solution to the problem and may require large amounts of water. Typically, farmers apply 6 to 24 inches of water to a field so salts as deep as where roots extend are removed. In many cases, growers may have to install a drainage system to ensure the salt is carried away.

Region wide, Cardon sees his lab's remote sensing techniques being used to do more than help farmers. Knowing current salinity levels around the state may help researchers understand future changes brought on by climate change, drought and water distribution policies. Using the baseline determined through remote sensing, researchers can create models based on climate or watershed water level predictions to see how these changes could influence Utah's salinity landscape. As the technology becomes more consistent at reading salinity levels, Cardon hopes that it can be used on even larger tracts of land to evaluate salinity globally. – ET

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on and research technician Bob Clawson use electromagnetic induction to arch in Cardon's lab focuses on understanding the impacts of soil components matter content to produce more accurate measures of soil salinity which over the world.

Utah's Water Future

by Simon Wang

Assistant Professor, Department of Plants, Soils & Climate
Assistant Director, Utah Climate Center

Drought and heat are no strangers to Utah. The proud residents of the nation's second driest state have in the past century built dams, dug cannels, drilled wells and used every source of water to build sustainable towns and cities. Today this massive and sophisticated water supply system dutifully supports 2.9 million people, providing convenient and plentiful water for irrigation, homes and electricity. When there was not enough precipitation, more groundwater was pumped; when there was too much, we pumped it out to the desert. We controlled water. On the few occasions we teetered on the brink of real drought, our mountains – reservoirs of frozen water – and a little extra snow would always save the day, and so it will again.

Or will it?

Modern settlements in Utah are barely 150 years old. But data describing the climate of a deeper past — a paleoclimate — tell a story of conditions often different from the ones the state's modern residents have experienced. The climate information stored in tree rings reveals episodes of drought much longer in time and deeper in magnitude. Such prehistoric mega-droughts (by modern standards) were not only common in the past millennium but periodic, having come and gone every 50 years or so. The perceived severity of droughts of the 1930s and 1950s was no match for droughts of the hundred years before. Additionally, while our most recent drought, lasting from 2000-2004 and responsible for the record low water level of Lake Powell, was the worst in 800 years for its intensity, it's duration was, by comparison, mercifully short.

Then came 2013. By July 2013, all Utah counties were federally declared as drought disaster for the second year. In Salt Lake City, August daily minimum (mostly nighttime) temperatures not only broke the previous record but shattered it by 3 degrees Fahrenheit — a true outlier! Moreover, July and August's mean temperatures set new records going back more than a century. As of September, more than half of Utah's reservoirs were below 50% of capacity and dropping. High temperature combined with shallow water also degraded water quality. Being a kayaker myself, it proved

Photo: Gary Neuenswander

difficult to find lakes with deep water, free of mud and stench, by late summer.

We need a winter with big snow.

For the past 60 years, Utah's precipitation has exhibited a clear oscillatory feature alternating between wet and dry periods every 10-15 years. This unique "wet/dry cycle" is highly influenced by the Pacific Ocean's slow changes over a similar period; warm water pools in the central tropical Pacific, then transitions to cool water over the next six years or so. As it turns out, winter precipitation over Utah, especially northern Utah, is affected by this cycle. Specifically, a wet cycle develops about three years after the Pacific waters begin their transition from warm to cool; similarly, a dry cycle develops about three years after the Pacific waters begin their transition from cool to warm. This provides a climatic signal, allowing scientists to forecast Utah's precipitation change, years in advance. The climate faculty in USU's College of Agriculture and Applied Sciences, including myself, with support from the Utah Agricultural Experiment Station, researched this approximately three-year time lag extensively within the 10-15 year cycle. It is important to note that this Pacific influence is not to be confused with the better-known El Niño/La Niña phenomenon. El Niño/La Niña only explains less than 20% of Utah's precipitation variation, and such a mild impact prevents operational prediction models from producing reliable seasonal forecasts beyond one month. The late Fredrick Liljegren of the Bureau of Reclamation once said, if he could have 20% confidence in any prediction for the next season, he'd be happy.

Our research group has been working hard to make Fred happy: In a 2010 paper published in the Journal of Hydrometeorology, we have predicted that the years of 2012 and 2013 will be at the driest phase of the 10-15 year wet/dry cycle with a climbing lake level. This has proven to be the case given 2013's continued drought status of the state. The good news is we may soon begin to enter the recovery phase of this drought cycle. Three years from now we shall see at least one winter with above-normal snowfall. As to this coming winter of 2013-14, models are predicting a near normal, slightly warm and dry snow season. That means it is unlikely we'll see a break from the two-year-old drought. Even though there is a chance for above-average precipitation, it's not something we should plan on from a risk-management perspective. Consequently, water managers are worried.

Back-to-back drought is what water managers in the West are uniformly concerned about. Any drought longer than two years rapidly reduces water reliability and severely strains our water supply systems, and Utah is prone to such drought. In 2012 the research team held a "water-climate roundtable meeting", where 12 governmental and other private water agencies were presented with the latest research on water and climate. The meeting's intent was to connect regional water managers with years of research and help them seek solutions to current and future challenges in water resources. The meeting produced marked interest in paleoclimate data and the need for climate (rather than weather) prediction in order to mitigate water demands from a growing population. Everyone recognized that water supply estimates driven by paleoclimate data could fundamentally assist in planning. Meanwhile, those mega-droughts of the past millennium, seen through the eyes of trees, could be persuasive to the public and policymakers alike, that the severe water shortages of the distant past may reappear with or without a warming climate.

Over two-thirds of Utah counties depend on groundwater for at least 70% of their public supply. Everyone can see a shrinking snowpack in the mountains, but falling levels of groundwater are invisible to public eyes. The fact that groundwater levels across Utah have been declining since the late 1970s poses a threat to farming. Fights over groundwater — "water grabs" — threaten rural communities and wildlife as people compete for water rights. A vivid example is the long-running fight over eastern Nevada's groundwater, some of which flows into Utah and supports some of the driest parts of the state. This legal battle for water won't dry up anytime soon, though it will become increasingly costly. Not surprisingly, we have found that Utah's groundwater fluctuates in concert with our 10-15 year wet/dry cycle, meaning that multi-year droughts can and will worsen groundwater depletion, drying up wells and fueling yet more water grabs.

What do we do?

The Bureau of Reclamation has already announced that water supply of the mighty Colorado River will no longer meet its current water demand. To mitigate for foreseeable water shortage, Utah has implemented statewide water conservation programs aiming for a 25% reduction by 2050. However, if future population projections are accurate, an additional 540 million cubic meters (approximately 440,000 acre-feet) will still be required over and above conservation to meet anticipated demand. Meeting future demands under variable climate conditions further challenge water suppliers to provide for agricultural and urban water users. This is a delicate problem requiring all sides of expertise, from climate science to political science, from hydrological engineering to water managing. It is a challenge, but also an opportunity; an opportunity to open dialogues and open minds.

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