# Water for Food Security:

## From Local Lessons to Global Impacts

Proceedings of the 2017 Water for Food Global Conference
Lincoln, Nebraska, USA | April 10-12

Water for Food
GLOBAL CONFERENCE
at the University of Nebraska

Proceedings of the 2017 Water for Food Global Conference, April 10-12
Lincoln, Nebraska, USA.

## Citation

Robert B. Daugherty Water for Food Global Institute at the University of Nebraska (2017).

Proceedings of the 2017 Water for Food Global Conference. Lincoln.

*Comments and questions may be directed to:*
Molly C. Nance, Director of Communication and Public Relations
Robert B. Daugherty Water for Food Global Institute
Nebraska Innovation Campus
2021 Transformation Drive, Suite 3220 | P.O. Box 886203
Lincoln, NE 68588-6203 USA
+1 402.472.5145 | mnance@nebraska.edu

## Credits

**Executive Editor**
Molly Nance

**Managing Editor**
Dana Ludvik

**Writer**
Doug Merrey

**Co-writer, proofing**
Kindra Foster

**Proofing**
Karen Hansen

**Photography**
Brett Hampton

**Design Direction**
Craig Eiting

**Design**
Firespring

**Additional Photos**
IFPRI, cover
Don LaVange, back of contents page
T. Krupnik, CIMMYT, pg. 1
S. Storr, CIMMYT, pg. 3
Neil Palmer, CIAT, pg. 4
Ollivier Girard, CIFOR, pg. 7
Georgina Smith, CIAT, pg. 20
Derrill Grabenstein, pg. 21
Lau San Román, pg. 23
Bhushit Agarwal, pg. 27
Jimmy O'Keeffe, pg. 35
Jane, Flickr, pg. 52
Anouk Delafortrie, HECO, European Union, pg. 53
Yofre Morales Tapia, CESVI, European Commission, pg. 56
Google Earth, pg. 63
Sandipani Chattopadhyay, pg. 78

Water *for* Food
DAUGHERTY GLOBAL INSTITUTE
*at the University of Nebraska*

DON LAVANGE

Presented By

Water for Food
DAUGHERTY GLOBAL INSTITUTE
at the University of Nebraska

## Conference Sponsors

Gold Sponsor — MONSANTO

Silver Sponsor — Senninger®
AGRICULTURAL IRRIGATION | A Hunter Industries Company

Bronze Sponsor — Nebraska CornBoard

Supporting Sponsor — LI-COR Biosciences

## Supporting Partners

USDA

NDMC NATIONAL DROUGHT MITIGATION CENTER
AT THE UNIVERSITY OF NEBRASKA-LINCOLN

## Media Partners

The Water Network

AgWired
NEWS FROM THE WORLD OF AGRIBUSINESS

# Contents


Water for Food
DAUGHERTY GLOBAL INSTITUTE
at the University of Nebraska

# Foreword


*Farmer harvests wheat in Bangladesh*

Water and food security is personal.

It's a topic that affects each of us – and our children, our grandchildren and future generations. Those born in this century will grow up in a world where water and food security is a struggle in many areas.

This is a challenge more urgent than infectious disease, more consequential for international security than ISIS. We must come together to figure out how to sustainably feed a global population that will exceed 9.6 billion by 2050 – and soon.

That's where the University of Nebraska's Daugherty Water for Food Global Institute comes in. The institute, established in 2010, leverages Nebraska's rich history and leadership in agricultural production and water management to build partnerships across our state, country and world to explore research, create technologies and share relevant knowledge. Now in its seventh year, the institute's annual Water for Food Global Conference has become one of the key convening events for scientists, farmers and ranchers, policymakers, educators and others around the world who are seeking solutions.

We're making progress. As you'll see in the following proceedings, our most recent conference, developed around a theme of "Water for Food Security: From Local Lessons to Global Impacts," offered a range of presentations to the 425 attendees who joined us in Nebraska. We learned about innovations in sustainable irrigation in Africa, governance of major river basins and groundwater, and new technologies to improve water use

*Full presentations from the conference are available on our YouTube channel.*
**youtube.com/WaterForFood**

efficiency in producing food. We heard local case studies that yielded valuable lessons that could be adapted elsewhere around the world.

Innovative solutions come from gaining fresh and diverse perspectives. We were pleased to be joined by leaders who shared experiences from around the world: research projects that achieved groundbreaking solutions and some that failed despite best efforts; new approaches to influencing water and agricultural policies; ways to improve agricultural production in developing areas; and many other topics.

We thank everyone who attended, as well as conference sponsors and partners who provided valuable content and support. We invite you to review the insights gained during the 2017 conference and join the discussion as we work toward our common vision of a water- and food-secure world.

Hank M. Bounds, Ph.D.
*President, University of Nebraska*
*Chair, Daugherty Water for Food Global Institute Board of Directors*

Peter G. McCornick, Ph.D., P.E., D.WRE
*Executive Director*
*Daugherty Water for Food Global Institute*

# INTRODUCTION

S. STORR, CIMMYT

Water *for* Food
DAUGHERTY GLOBAL INSTITUTE
*at the University of Nebraska*

NEIL PALMER, CIAT

# Introduction

**For me [the challenge of water and food security] means the glass is half full. … The tremendous advances in research and technology offer opportunities for change.**

JEFF RAIKES, CO-FOUNDER, RAIKES FOUNDATION

Jeff Raikes
*Co-Founder, Raikes Foundation*

The 2016 conference, "Catalytic Collaborations: Building Public-Private Partnerships for Water and Food Security," set the stage for this year's event, which expanded upon many of the previous topics. In his opening remarks, Jeff Raikes, co-founder of the Raikes Foundation and outgoing chair of the DWFI board of directors, said he realizes that for many people, the challenges we face mean the glass is half-empty. "For me, it means the glass is half-full," he said. He talked about growing up on a farm and seeing the power of science and technology to bring about advancements that made people's lives better. "The tremendous advances in research and technology offer opportunities for change, as long as we use our efforts in the right place," he said. This was a major theme throughout the conference.

Michael Boehm
*Harlan Vice Chancellor, Institute of Agriculture and Natural Resources, University of Nebraska–Lincoln; University of Nebraska Vice President for Agriculture and Natural Resources*

The Daugherty Water for Food Global Institute, Raikes said, benefits from the deep expertise in Nebraska, with a vision to invest in viable solutions that make a difference in the world. He cited the work of the institute's Faculty Fellows in applying remote sensing and web-based technologies to improve water and food security, working with local farmers, and partnering with others around the world. The conference theme, "From Local Lessons to Global Impacts," is about all of these threads coming together. "Global change begins at home," Raikes explained. "We must collaborate to ensure innovations are successful — to make sure they take root."

The challenge, Raikes warned, would be to make new connections. "We have a huge challenge," he admitted, "but … the people at this

> **Today [the conference] will bring even more to the table for our feast of research and education in water and food security, as we think about local lessons and how they can make global impacts.**
>
> MICHAEL BOEHM, UNIVERSITY OF NEBRASKA-LINCOLN

conference have the power to achieve water and food security." After his presentation, Raikes was given a special award by the Daugherty Water for Food Global Institute, in recognition for his work on the board of directors. Raikes is stepping down from the board this year to pursue other leadership interests.

Opening the Wednesday plenary, Michael Boehm, Harlan Vice Chancellor at the Institute of Agriculture and Natural Resources, University of Nebraska–Lincoln (UNL), and University of Nebraska Vice President for Agriculture and Natural Resources, reiterated the idea that conference attendees were learning about many "super audacious and bold solutions." He said he is pleased to see Nebraska faculty and staff working toward food and water security from local to global contexts — aligning with the conference theme.

The distinguished speakers generated new thinking and dialogue among the participants, and set the scene for the more focused technical sessions. Crosscutting the main "Local Lessons to Global Impacts" conference theme were five critical focus areas: water for food security in Africa; agriculture in a water-scarce world; technological innovations for increased water productivity; water governance; and responding to the impacts of climate change on water and food security. The Africa, technology and governance focus areas built on the 2016 conference outcomes.


*University of Nebraska President Hank Bounds (left), Chairman of the Robert B. Daugherty Foundation Mogens Bay, and DWFI Founding Executive Director Roberto Lenton present the "Water for Food Champion" award to Jeff Raikes in honor of his leadership and service on the DWFI board of directors*

# WATER FOR FOOD SECURITY IN AFRICA

OLLIVIER GIRARD, CIFOR

# Water for Food Security in Africa


*Robert Bertram, Chief Scientist, U.S. Agency for International Development*

Robert Bertram, chief scientist at the U.S. Agency for International Development (USAID), continued the "glass is half-full" perspective articulated by Raikes. He said that access to water is critical for ending hunger and malnutrition in Africa, and there are "a lot of things to be happy about." We now have a good understanding of the link between agriculture and growth, and recognize that there is no single magic bullet solution. Further, the world has made a clear commitment to end hunger by 2030, and the U.S. Government has enacted the Global Food Security Act (2016) — "a bipartisan endorsement of our progress over the last decade," he said. "So, things are getting better."

The world has seen major reductions in hunger and poverty. However, Africa is lagging. Bertram said agricultural growth is twice as effective at reducing poverty as other methods. "Agriculture also reduces hunger. It links with the rest of the economy." The American government's "Feed the Future" program has three major drivers: increasing food production, improving access to water and sanitation, and raising women's status. "It's a key factor. Improved status makes women better [resource] users and decision-makers," he explained.

Climate change is a critical driver, but Bertram emphasized that farmers have always dealt with drought and weather extremes. "There's nothing like water stress to stress agricultural communities," he said. "What if we could manage water better in these environments?" However, "we [not only] want to reduce risk, but also foster investment" by linking farmers to markets and raising productivity. Even if a two-hectare small rainfed farmer adopts all the available crop recommendations, she will not escape poverty. She must do more, but innovations are risky. Water is the critical ingredient for risk reduction and increased income.

Bertram said that small-scale irrigation has been an overlooked source of improvement. "Irrigation links to mechanization and higher-value, nutrient-rich crops — which link to technology and policy. What will it take to unlock the potential?" Bertram said we need to increase access to water, catalyze smallholder value chains, create policy synergies between sectors, and take a watershed perspective.

> **Irrigation links to mechanization and higher-value, nutrient-rich crops — which link to technology and policy. What will it take to unlock the potential?**
>
> ROBERT BERTRAM, CHIEF SCIENTIST, U.S. AGENCY FOR INTERNATIONAL DEVELOPMENT

*Timothy Williams, Director for Africa, International Water Management Institute*

He reviewed innovative work by U.S. Feed the Future partners on promoting new technologies, such as solar pumps, and implementing new business models. But Bertram emphasized that more work is also needed to incorporate gender in the solutions.

Sithembile Ndema Mwamakamba, of the Food, Agriculture and Natural Resources Policy Analysis Network (FANRPAN), talked specifically about the role of smallholder irrigation. Irrigation can play a significant role in increasing crop yields, but irrigation development has been slow in Africa, and the productivity of irrigated agriculture is only about a third of Asia's. She emphasized that the challenges are counter-balanced by important opportunities, including underutilized water resources; growing demand for high value products; renewed public and donor interest in irrigation and recognition of the need for research-based evidence to guide investments; and the commitment of African governments to achieving the Sustainable Development Goals (SDGs).

Focusing on achieving gender equality, responding to climate change impacts, increasing smallholders' access to water for irrigation, catalyzing smallholder value chains and promoting agricultural businesses were themes that resonated throughout the sessions on Africa.

## Upscaling Irrigation Solutions in Sub-Saharan Africa

A major focus of the conference was upscaling successful experiences and lessons learned to rapidly expand African small-scale farmers' access to irrigation. The promising case studies, combined with a session devoted to an in-depth analysis of Ethiopia's experiences, provided more evidence

that "the glass is half full": considerable progress has been made and, more importantly, the lessons learned provide a firm foundation for scaling successful innovations up and out. There was a consensus among the participants that expanding small-scale irrigation in sub-Saharan Africa is critically important to achieving food security and promoting economic growth.

Eight case studies illustrated the great variability among African farming systems and, therefore, of potential solutions. These included promoting low-cost irrigation technologies through private sector markets, more effectively supporting community-managed irrigation systems to be successful businesses, and pilot testing promising new technologies.

The session moderator, Timothy Williams, director for Africa at the International Water Management Institute (IWMI), began by asking, "What will be the ways to expand access to irrigation for small farmers in Africa?" African agriculture is mostly rainfed now, but increasing variability in rainfall is making this more precarious. Emphasizing a point also made by Bertram, Williams said, "African farmers must switch to using irrigation, not only to feed themselves, but to feed their country, the continent, and for exports." He emphasized that farmers need social and institutional solutions as well as better technologies. Out-migration of young people is currently a major challenge, but irrigation can provide employment, as well as farm and nonfarm business opportunities.

Williams outlined the kinds of measures needed to promote irrigation expansion: reform of land tenure and secure water access; access to inputs and equipment, many of which are too expensive for most farmers; access to credit, advisory services and markets to make agriculture profitable; and supportive government policies, such as reducing taxation bottlenecks and creating incentives to encourage investment. The case studies illustrated the importance of these themes.

> **African farmers must switch to using irrigation, not only to feed themselves, but to feed their country, the continent, and for exports. Social and institutional solutions are needed in addition to better technologies.**
>
> TIMOTHY WILLIAMS, DIRECTOR FOR AFRICA, INTERNATIONAL WATER MANAGEMENT INSTITUTE

***Solutions from NGOs.*** Three case studies were presented by NGOs: one each by iDE and KickStart International, both international nonprofit social enterprises, and one by a representative of a Catholic diocese in Ghana. iDE and KickStart share an ambition to assist millions of small farmers to become successful businesses linked to functioning markets. Both are trying to scale up the use of low-cost modern technologies that improve the returns on farmers' labor and enable smallholders to profit from irrigated agriculture.

Timothy Prewitt, CEO of iDE, explained that his nonprofit social enterprise focuses on creating income and livelihood opportunities for poor, rural households. Prewitt said that "iDE has been putting business to work for the poor for more than three decades, using market-based solutions to change the living conditions and livelihoods of millions of people around the globe."

Climate is a major risk — a theme repeatedly brought up at the conference. "By 2030, nine of the 10 major food crops will experience reduced or stagnant growth rates," Prewitt said, which will cause food price increases. "No one is more at risk from price increases than the small farmer." But the

good news according to Prewitt is that 500 million small farms today produce food for 2 billion people. Because there is a large number of small farms, he explained, it is difficult to generalize what's needed to help farmers. But one need consistent across the world's group of small farmers is technology.

Prewitt emphasized that not every iDE project has been a success. "We've had a ton of failures," he explained, but he noted that iDE has achieved important successes. For example, a recent pilot test of Farm Business Advisors (Box 1). "The advisors are like Avon ladies," he explained. "They provide trust-based value. We've helped 340,000 people get access to technology through this system. It's simple earned commission. The advisors provide products, advice and help with loans."

> **iDE and the Daugherty Water for Food Global Institute have a shared mission to create big change on shoestring budgets and make it happen in a way that's good for the people it impacts.**
>
> TIMOTHY PREWITT, CEO, iDE

Drip irrigation is a good example of a product that can help smallholder farmers increase income. "We need products stripped to their essentials, with low cost, low pressure, functionality in poor water-quality conditions, and adaptability to a range of crops," he said. Prewitt said that smallholder farmers can purchase drip irrigation kits for as little as $175, which can increase crop yields by 20 percent. The projected market for drip irrigation

BOX 1

## Farm Business Advisors: A Cost-effective Approach to Building Agricultural Value Chains?

iDE developed a pilot project in Zambia to test the cost-effectiveness of "farm business advisors" (FBAs), described as "independent commission-based entrepreneurs" who go from one remote village to another, promoting the growth of high-value cash crops (such as soya beans). iDE-trained FBAs improved access to seeds, introduced technology that increases crop yields, and connected farmers to buyers for these new crops.

Over time, the cost of fielding FBAs declined drastically as the number of clients increased: on average, one FBA serves 132 client farmers. Prewitt noted that, since iDE launched the program, "more than 339,000 farmers have benefited, generating an average of $423 [per farmer] annually." The FBAs have also benefited: their average annual income is $803, earned from multiple sources, including commissions on equipment sales, fees for services, percentage of profits from aggregation of farm outputs, and sometimes salaries paid by iDE. The salaries helped FBAs build relationships and strengthen business connections at critical points on the value chain. When these relationships became self-sustaining, iDE phased out support. Factors contributing to this success include a built-in data feedback loop, sales training for FBAs and adaptive, flexible management.

The system has won awards, including a Harvard Business School Case Method award.

products is potentially huge — $21 billion. "When something like this does work, it can really increase income," he said. Here's the vision: What if we could get one million farmers to use less water?

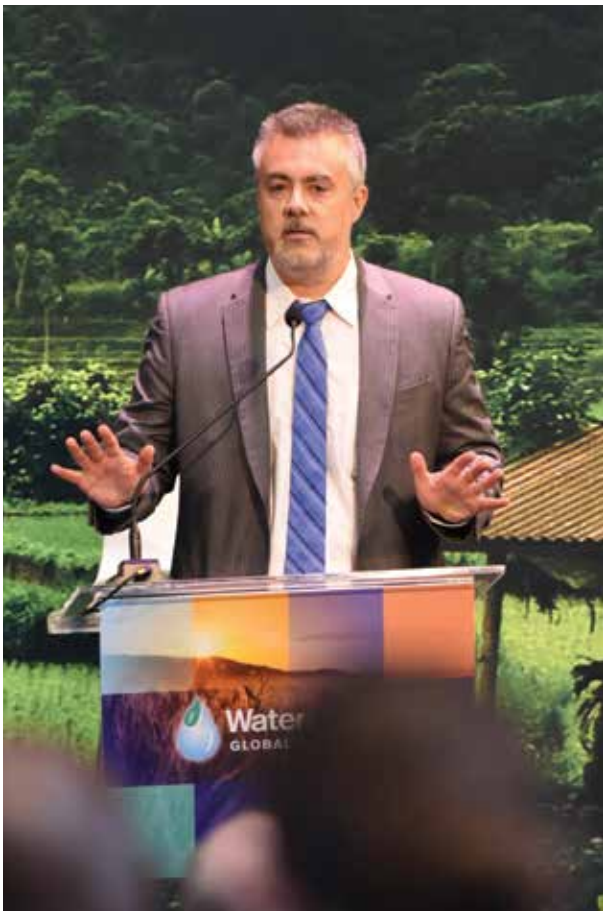
Prewitt concluded that "iDE and the Daugherty Water for Food Global Institute have a shared mission to create big change on shoestring budgets and make it happen in a way that's good for the people it impacts."

KickStart International is another important nonprofit helping smallholders achieve greater yields through personal powered irrigation pumps. Martin Fisher, co-founder and CEO, explained that its "mission is to enable millions of families in Africa to climb out of poverty — by earning a lot more money." Echoing Prewitt and others, he said the best way for them to escape poverty is to move from rainfed to irrigated farming, enabling them to harvest crops year-round, diversify into higher value crops, obtain higher prices and reduce postharvest losses.

Fisher said that treadle pumps offer the lowest cost solution for poor farmers with little capital, but with access to shallow groundwater, small streams or ponds. KickStart now produces several pump models, all of which are small, durable, easy to use and repair, and energy-efficient. Retail prices range between $90 and $160.

KickStart established a private sector supply chain extending from manufacturers in China to local shops. All parties involved earn a profit — there are no subsidies. Donor funds are used for social marketing campaigns, demonstrations and training.

The irrigation pumps constitute a major capital expenditure for the farmers, but the benefits can be dramatic. KickStart monitors the impacts on families purchasing a pump. According to Fisher, these farmers' profits average $700 per year. From 2000 to July 2015, KickStart sold 270,000 pumps, benefiting 200,000 local farm businesses and creating 180,000 jobs. Total earnings are about $170 million per year. Over 1 million people have escaped poverty, and pump users are feeding fruits and vegetables to some 10 million people.



*Timothy Prewitt, CEO, iDE*

KickStart is now launching a new strategy in 15 countries to help another million people escape poverty by 2021. It is shifting from working only through retail stores to also working through and leveraging new partners, including other NGOs, financial institutions, businesses and governments.

Fisher noted that by 2021 "the population in Africa will grow by 200 million." Therefore, it is critical to develop new irrigation technologies and find innovative ways to promote uptake more quickly. Partnerships are the key. For example, KickStart is collaborating with World Vision in Zambia to expand lending; after all, irrigation reduces the risks involved, making lending more attractive. A new $45 starter pump is launching in September

2017. And KickStart has partnered with an American company to produce a low-cost portable solar pump to be introduced in April 2018.

***Other innovative technologies.*** Other potential innovative technologies show promise in improving smallholders' business opportunities. Meredith Giordano, from IWMI, presented the results of a project examining the suitability of solar irrigation pumps in Ethiopia. An estimated 7 million hectares potentially could be irrigated using pumped ground and surface water. The study found that solar pumps are indeed economically feasible, reduce labor costs, and benefit women even more than men because they can be used for multiple purposes, such as obtaining domestic water. Farmers can earn extra income, for example, by charging batteries.

Giordano explained that many conditions in Ethiopia are favorable for expanding solar pump use. Demand is very high because both men and women prefer them to other types of pumps; there are good potential markets for selling produce, as well as high value commodities such as coffee; there are government programs aimed at encouraging renewable energy use in agriculture; there is no custom duty on imported pumps; and there is some potential for financing. Donor-funded projects already are introducing solar pumps.

However, Giordano also pointed to some constraints, including difficulties farmers have in accessing information and incentives; underdeveloped value chains; domestic production potential still not realized; limited rural finance; and low capacity for installation, services and repairs. Pumps cost an average $350 — more than twice the price of KickStart's solar pumps — but the return on investment was also high. Plans are underway to further pilot-test several investment scenarios. This example illustrates the need for systemic infrastructure and policies for scaling up new technologies.

Richard Berkland, from the Global Irrigation Division of Valmont Industries, Inc., reported on CIRCLES — a project designed to make center pivot irrigation a viable option for smallholder farmers in Africa. Berkland sees great potential for several smallholder farmers to cultivate under one center pivot irrigation system if costs can be reduced and viable business models are developed. He explained that adding additional spans to increase the pivot length expands the potential irrigated area at a reduced cost per hectare. In other words, while a small pivot can be prohibitively expensive per hectare, at the 40- to 75-hectare size, the cost is more affordable at $2,500-4,000/hectare.

**It is critical to develop business models for small-scale public irrigation schemes that are both financially and environmentally sustainable and socially equitable.**

Berkland said his goal is to demonstrate how smallholder farmers can dramatically increase net household income by farming under center pivot irrigation. Success requires using modern methods in irrigation, seeds, tillage, fertilizer and pest control; flexible, affordable credit and the opportunity to build equity; access to local, regional, and export markets; and institutional support that empowers farmers and their communities.

Community-managed small reservoirs offer another approach to making irrigation available for smallholder farmers. There are thousands of such reservoirs in sub-Saharan Africa, accounting for nearly half of all irrigated land. They have tremendous potential, but have consistently underperformed. It is therefore critical to


*Sithembile Ndema Mwamakamba, Climate Smart Agriculture Program Manager, Food, Agriculture and Natural Resources Policy Analysis Network*

develop business models for small-scale public irrigation schemes that are both financially and environmentally sustainable and socially equitable.

Sithembile Ndema Mwamakamba, climate smart agriculture programs manager with FANRPAN, described a study aimed at increasing irrigation water productivity in six irrigation schemes in three southern African countries: Mozambique, Tanzania and Zimbabwe, through on-farm monitoring, adaptive management and promotion of agricultural innovation platforms.

She explained "the barriers to improving farm productivity and profitability in small-scale irrigation schemes are a broad and complex mix of institutional, market, infrastructure and production issues." Further, they cannot afford small-scale equipment, such as power tillers. "Manual systems can erroneously appear to be low-cost alternatives." This is similar to a point made by Tim Prewitt of iDE: there is a need for practical low-cost technologies that enhance labor productivity. The project used innovation platforms to represent diverse stakeholders and empower local dialogues. She concluded that "there is no universal formula for replication, and approaches need to be adapted to local conditions." Mwamakamba listed four key lessons from FANRPAN's research:

1. Because small-scale irrigation schemes are complex systems, multiple, concurrent interventions are required to transform them to more profitable and sustainable states.
2. It is as important to invest in people as it is to invest in hardware to achieve success: "Soft barriers were most limiting for the farmers."
3. Governments need to clarify their objectives and empower farmers. Farmers should be encouraged to produce profitable crops for local

markets, and to expand their enterprise where they can.

4. Effective markets provide both the incentive and the means to invest. "In our view," she said, "it is this positive reinforcement from the agricultural market that will maintain more sustainable and profitable irrigation."

The lessons learned from a case study in Ghana support the findings of FANRPAN's study in southern African countries. Ayembilla Joseph Anyagbilla from the Navrongo-Bolgatanga Catholic Diocese said their project supported construction of a small earthen dam for dry-season irrigation. Farmers invested land and labor, while the Diocese invested nearly $150,000. The dam now irrigates about 30 hectares, cultivated by 150 onion farmers (including 60 women) and 58 local vegetable farmers (including 23 women). The project is considered a success because it was based on community demand, the Diocese covered the direct investment costs and invested in capacity development, and the community adopted bylaws to enable it to manage the dam. Although several technical, financial and institutional bottlenecks remain, the community gained support from the local government to address these problems. The Diocese also has learned important lessons it will use to scale-up such projects in the future. The two most important lessons are to add a contract agreement with the Ministry of Food and Agriculture to continue to provide agricultural advisory services to farmers; and to conduct a thorough business opportunity analysis before deciding which crops to promote.


*Ruth Meinzen-Dick, Senior Research Fellow, International Food Policy and Research Institute*

These two cases offer valuable lessons for designing programs to enhance the productivity, profitability and equity of community-managed irrigation schemes. The main lesson is that, to make the programs work, investment in hardware needs to be accompanied by investments in "software" — community capacity to manage the scheme, and value chains to make irrigated agriculture profitable.

***Empowering women.*** Providing opportunities for women to gain access to productive resources and markets has been shown to lead to enormous benefits, as emphasized by Bertram and others. But implementation often faces many obstacles. Ruth Meinzen-Dick, senior research fellow with the International Food Policy and Research Institute (IFPRI), explained the use of the "Women's Empowerment in Agriculture" index, as modified to specifically include irrigation. The index is an intra-household survey instrument that measures women's empowerment in five domains: production decision-making, access to productive resources, control of income use, community leadership and time allocation. The results were not consistent across countries: for example, women from irrigating households in Tanzania and Ghana have higher empowerment scores than in Ethiopia. Factors disempowering women also vary in importance across countries, but some common examples include the inability to participate meaningfully in groups, lack of leisure time and limited access to credit. Meinzen-Dick noted that "a big issue in developing value chains is, are

> **A big issue in developing value chains is, are we taking control away from women who use vegetables at home, when men take them to sell?**
>
> RUTH MEINZEN-DICK, SENIOR RESEARCH FELLOW, INTERNATIONAL FOOD POLICY AND RESEARCH INSTITUTE

we taking control away from women who use vegetables at home, when men take them to sell?"

The index gives a snapshot of women's empowerment, and enables diagnosis and tracking changes. It is already being used by 60 organizations in 39 countries.

***Scaling up irrigation investments in the Sahel.*** So how can African irrigation innovations move from local experiments to large-scale adoption and impacts? One project in West Africa, the Sahel Irrigation Initiative, is an ambitious attempt to answer this question. Francois Onimus, senior water resources specialist at the World Bank, described an innovative six-country regional project in West Africa designed to learn and share lessons on scaling up profitable and sustainable irrigation investments. Onimus explained that "countries and their development partners keep repeating the same mistakes," and current approaches are not conducive to private sector investment. "Irrigation scale-up will only happen through a bold institutional modernization, bringing agility to the sector through a systematic and holistic capacity building effort," he said.

The regional task force has developed a common framework and obtained political commitment to the program. The emphasis is on "doing business differently." This approach will enable economies of

BOX 2

## Panel Discussion: What are the Key Lessons on Scaling up Irrigation Access in Africa?

Following the presentation of African irrigation cases, a panel discussed the key lessons, including factors contributing to success, as well as barriers and risks. Key points:

"Smallholders are still relevant for food security," said Mbogo Futakamba, retired Secretary of the Ministry of Water and Irrigation in Tanzania. He noted that Tanzania has a very large irrigation potential, and emphasized the important role of research institutions in identifying affordable technologies and strong policy support.

USAID Water and Irrigation Advisor Biniam Iyob emphasized that demand is necessary for success. Market analysis is critical to ensure that the product is what consumers want, at the right price. He also noted the importance of research and capacity development, and pointed to two bottlenecks: land tenure and access to finance.

Timothy Williams of IWMI agreed that the successful cases are those that start with economic objectives, producing the right crop that is profitable. But he also noted important constraints; for example, "even small-scale irrigation is an elitist technology." The costs of pumps and drip kits are too high for many smallholders, especially women and young people, reinforcing the importance of access to credit. He recommended "leveraging the multiplier effects of irrigation," for example, encouraging new businesses, such as irrigation service providers.

IFPRI's Ruth Meinzen-Dick emphasized the importance of gender-equitable irrigation. There is a lot of evidence that gender matters, because men and women have different roles, preferences and constraints. Women need time-saving small-scale household technologies, land tenure rights and a stronger voice in decision-making at the community level.

Francois Onimus made an important observation: "When scaling out, the devil is in the details – large projects are more complicated than pilot projects."

*Francois Onimus, Senior Water Resources Specialist, World Bank*

scale in delivering services (e.g., technical assistance, capacity building, research, monitoring and evaluation), and the larger market size for irrigation equipment will make it more attractive for private suppliers to invest. The project will constitute an "innovation lab" to expand successful experiences.

> **Irrigation scale-up will only happen through a bold institutional modernization, bringing agility to the sector through a systematic and holistic capacity building effort.**
>
> FRANCOIS ONIMUS, SENIOR WATER RESOURCES SPECIALIST, WORLD BANK

## Ethiopia: Lessons Learned in Water and Food Security

*A special conference session reflected on Ethiopia's experiences and lessons learned.*

***Drought response.*** Tsegaye Tadesse, an associate professor, climatologist and remote sensing expert in the National Drought Mitigation Center (NDMC) at UNL, and a DWFI Faculty Fellow, noted, "For achieving food security, drought is the elephant in the room. Meeting this challenge requires a paradigm shift from crisis management to drought risk management." Drought is complex, multi-dimensional, and has natural as well as social dimensions. In Ethiopia, frequent droughts since 1900 have led to hundreds of thousands of people dying. In the 2015-2016 drought, more than 10 million people were affected and an unknown number died. And climate change is worsening the impacts of drought, as it is expected to cause an increase in extreme events, floods and droughts. Currently, the global community mobilizes to save lives during disasters, but we need to prepare and plan for how to respond to droughts and reduce their impacts.

Tadesse reviewed Ethiopia's responses to drought and the evolution of its policies. It now has a Disaster Risk Management Commission, but still takes action mostly in response to drought, rather than investing in preparation. NDMC is participating with the DWFI, United Nations and African institutions to prepare a drought risk management strategy, drawing on lessons from other parts of the world. Tadesse explained that strong partnerships, innovative financial solutions and leadership are critical for success: "Africans should find solutions to their own problems" and build a "drought-resistant Africa."

According to Tadesse, what is needed now in Ethiopia is political will and leadership, initial investments to build capacity, more collaboration within and between countries, engaged and supportive citizens and stakeholders, engagement of the research community, and outreach and media programs.

> **For achieving food security, drought is the elephant in the room. Meeting this challenge requires a paradigm shift from crisis management to drought risk management.**
>
> TSEGAYE TADESSE, ASSOCIATE PROFESSOR, CLIMATOLOGIST AND REMOTE SENSING EXPERT, NATIONAL DROUGHT MITIGATION CENTER

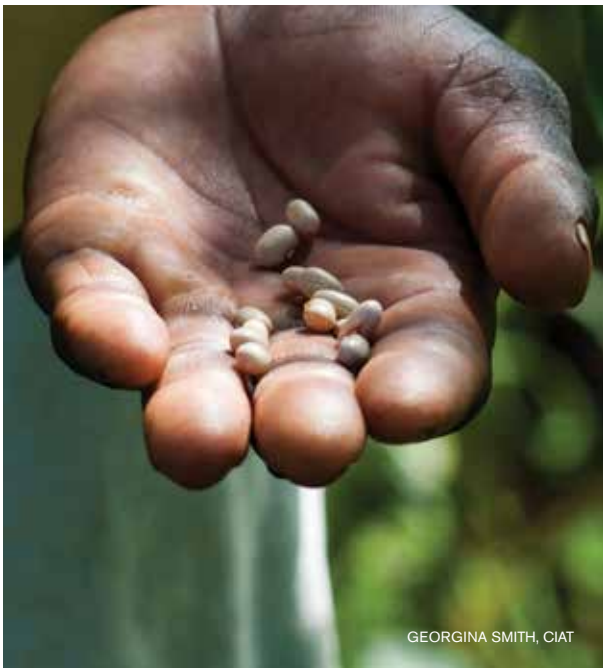
***Overcoming impediments to success.*** Patrice McMahon, associate professor, UNL Department of Political Science and a DWFI Faculty Fellow, said her views are "on the pessimistic side." She focused on the realities and challenges of incorporating local lessons and voices in development programs.

McMahon noted that Ethiopia is in many ways a "success story," citing its exceptional economic growth rate of about 10 percent and its stabilizing role in the region. Ethiopia is the top recipient of overseas development aid in Africa, on the order of $3.5 billion in 2013, constituting 50 percent of its budget. Until recently, economic development assistance was increasing, while humanitarian aid was decreasing. But less than one percent of this humanitarian aid goes to disaster preparedness. Ethiopia has its own development plans and priorities, which are supported by donors. However, despite this assistance, she claimed food and water insecurity are actually increasing, with 18 million people depending on food aid in 2016. Forty percent of the population is "chronically hungry," and the nation's human development index is low (173/186).

McMahon highlighted several challenges, especially questions about the effectiveness and targeting of water and other development assistance, and the reliance on project-type interventions. She said the latter issue came up frequently in her interviews of Ethiopians. McMahon is initiating further research to understand the political economy of development assistance for water in Ethiopia.

Building on the political economy theme, IWMI's Timothy Williams pointed to another impediment to more rapid progress, the "perverse outcomes of


*From left: Peter G. McCornick, Timothy Williams, Patrice McMahon, Nicole Wall, Tsegaye Tadesse and Roberto Lenton in the session, "Ethiopia: Lessons Learned in Water and Food Security"*




*African soybeans*

> **We need an exit strategy that empowers the local community to take ownership and run projects over the long term.**
>
> TIMOTHY WILLIAMS, DIRECTOR GENERAL FOR AFRICA, INTERNATIONAL WATER MANAGEMENT INSTITUTE

the urban and technological bias of development policies." He said he had seen many changes in his 30 years of visiting and working in Ethiopia — the country has vast natural resources, but every few years it faces a crisis. This reflects a failure of institutional support in the country, as McMahon noted. Panelists noted that Ethiopia receives a huge amount of aid, and it has experienced a rapid GDP growth rate, but this has not translated into "inclusive rural development."

Williams suggested two reasons for these problems. One is the urban bias in Ethiopia's — and other African countries' — development planning and implementation. Large and medium-sized cities have grown tremendously, but, he asked, why has this not translated to an equally impressive rural development? The other reason is the bias toward technology while underinvesting in institutions. Providing technology, such as pumps, is the easy part, but Williams argued that policymakers lack a good appreciation of the institutional and social requirements for successful technical projects. Williams emphasized that investment in hardware must be accompanied by investments in the "software" to make them work, a theme that emerged frequently.

Finally, Williams said, we need an exit strategy that empowers the local community to take ownership and run projects over the long term. Without this, we see a cycle in which we invest and build, the project degrades, and then we must rebuild. This cycle is found not only in Ethiopia, but in many other African countries and other developing regions of the world.

The lessons from Ethiopia's development experience are applicable across Africa. The case studies offer promising ideas that can be scaled out: making useful irrigation technologies such as solar and treadle pumps more widely available; implementing policies that strengthen a community's ability to manage irrigation schemes and make irrigated agriculture more profitable; encouraging private sector engagement in support of smallholders; supporting women's access to resources and opportunities; encouraging research support to promote innovation and shared knowledge; and a stronger emphasis on "software," such as capacity development, not only of farmers, but also policymakers and implementing agencies.


Water for Food
DAUGHERTY GLOBAL INSTITUTE
at the University of Nebraska

# THE WATER SCARCITY CHALLENGE: INCREASING WATER PRODUCTIVITY

DERRILL GRABENSTEIN

# The Water Scarcity Challenge: Increasing Water Productivity

One of the prominent conference topics revolved around the impacts of, and solutions for, water scarcity and its implications for food security. Brian Richter, president of Sustainable Waters and chief scientist in the Global Water Program of The Nature Conservancy, addressed this issue with respect to river basins. He pointed to the trends in water availability in two major river basins: the Murray-Darling in Australia and the Colorado River in the U.S. He said he has reviewed hundreds of similar graphs, and the story is nearly always the same: the water available in any river basin is highly variable, and demand from consumptive use eventually exceeds supply.

Water scarcity is spreading and intensifying: water shortages are occurring in one-third of the planet's watersheds and aquifers, affecting half of the world's population and three-fourths of the world's irrigated acreage. "That is the scariest thing," Richter said. The World Economic Forum has put water shortage at the top of its list of risks to the global economy. Half of western rivers in the U.S. have lost more than three-fourths of their water. This means "they are ghost rivers," he said, "and we need to ask ourselves, do we need eco-restoration or are we going to just make the best of what we have?"

How can we stop this from happening in so many places? Richter said many solutions, such as building water diversion projects, recycling and desalinization are expensive, and may not solve the problem in the long term. He believes the number-one solution is creating water through conservation. "Each gallon we don't consume," he said, "is a gallon available for other users, or nature." Water conservation, both urban and agricultural, also costs less than most other solutions.


*Brian Richter, President of Sustainable Waters and Chief Scientist in the Global Water Program, The Nature Conservancy*

Richter discussed some of the complexities — challenges as well as opportunities — involved in conserving water on farms. "We have to talk about agricultural productivity, not just water-saving potential." He took a glass half full view: "It's a difficult win/win/win, but I think the potential is there." This theme of increasing water use efficiency or water productivity on farms was a major focus of several technical sessions. An additional dimension of addressing water scarcity involves the tradeoffs between human uses of

water for agriculture, industry and cities, and either maintaining or restoring water-based ecosystems. This was a major theme of the sessions on governance, especially in the U.S. on the Colorado, Platte and Missouri Rivers.

## Water Productivity of Agricultural Systems

One potential solution to growing water scarcity is to increase the productivity of water — produce more "crop per drop." But measuring water productivity is a challenge. Research results are often inconclusive, but participants agreed new clues to increased agricultural productivity are likely to be found as research continues. Some results point to Nebraskan field management techniques that could be used in other parts of the world, including Africa, with greater results.

***Water conservation in agriculture.*** Susanne Scheierling, senior water economist at the World Bank, presented results from an ongoing study examining global trends in agricultural and total water withdrawals and consumption from groundwater. It is a challenge, she said, because data is scarce and there is considerable confusion in the definition of terms and measures used. Since the 1960s, water withdrawals basically have doubled. In the same period, the area equipped for irrigation also has doubled, accounting for much of the increasing water scarcity. Since agriculture uses nearly 70 percent of drawn freshwater resources, improvements in efficiency of agricultural water use would have large implications for addressing water scarcity issues. It should be possible to achieve higher agricultural production with the same water, or achieve the same levels of production with less water. Conserving water would enable reallocation to other uses.

However, Scheierling said, "This is a complex topic, in part because water itself is a uniquely complex resource, and because many disciplines are involved." People and organizations define terms such as "efficiency" differently and focus


*Green River, chief tributary of the Colorado River, in Wyoming, USA*

on different water measures. The policy and institutional setting is also important when studying water withdrawals, because it determines what farmers can do. Scheierling used the example of water rights tied to land: if a farmer uses an improved irrigation technology, he cannot expand the irrigated area. Reduced consumptive use can make water available for reallocation in this case.

Scale also matters: water conserved at the farm level does not tell you what is happening in the river. "In the end, you may have no water in the river, but your ratios may not have indicated that to you, because they are based on some plot and aggregated measurements," Scheierling said. "These ratios should be examined and treated carefully."

Scheierling concluded that "agricultural production and water conservation should not be seen as two sides of the same coin." She argued that there is scope for a lot of research. For example, we need more comprehensive economic assessments of agricultural water productivity and how water can be used more productively in different contexts and with various objectives. There is a "need to push" for improved availability of data on agricultural water use and greater collaboration among disciplines.


*Susanne Scheierling, Senior Water Economist, World Bank*

***Benchmarking irrigation performance.*** Two studies from Nebraska attempted to identify practical ways to increase irrigation water productivity. A study by Patricio Grassini, UNL cropping systems agronomist and a DWFI Faculty Fellow, is developing a framework for benchmarking and identifying opportunities to improve field-level irrigation management without affecting yields. There is a wide variation in irrigation amounts applied for corn and soybeans among irrigated fields in Nebraska, showing the opportunity for improving irrigation management. Data were collected over three years from 534 center-pivot irrigated fields. Variables studied included management, soils, weather, and wet versus dry years. Fields were grouped according to soil and conditions. They used two ratios: Relative Water Supply, the ratio of actual irrigation plus rainfall to the estimated requirement, and Relative Yield, the ratio of actual to potential yield.

The study found that 73 percent of maize and 41 percent of soybean fields used an irrigation "surplus." When they looked at fields with the largest and smallest amounts of irrigation over time, they found these remained consistent, suggesting they are a function of the irrigator's behavior — which is good news because it can be changed. They also found that "there is a neighboring effect," Grassini said. "If a farmer is applying water in a specific field, a neighboring farmer may also be tempted to apply water."

The next question is: Can we translate field-level savings to statewide savings? That is, how much water could be saved by Nebraska farmers if everyone adopts best irrigation management practices? Study results indicate that, in years with near- or above-average rainfall, producers can save as much as 50 percent of the water used by

*Christopher Neale, Director of Research, Daugherty Water for Food Global Institute*

irrigation. In drought years, the study showed only a 10 percent savings. There is, therefore, a substantial potential for water savings by Nebraska farmers, with important implications for the state's aquifers.

Mesfin Mekonnen, DWFI postdoctoral research associate, shared results of a study on improving water productivity in irrigated corn through varied irrigation strategies. The study examined the relationship between yield and irrigated water supply using field-level data, and found large variations in yields with the same water supply. Mekonnen asked, "Why do some farmers apply a different amount of water than others and get the same amount of yield?" During the 10-year time period of the study, there has been an overall decline in the amount of irrigation water applied, probably because of the shift to center pivots. "[But] there is still a huge variation in the water applied per farmer." The study reveals that a large number of farmers continue to over-irrigate, getting the same or lower yields than those who use less water.

> **Saving water may not be the story; but if saving energy is a way to get farmers interested, we might show them the bottom line benefits of reducing energy use and cost to get a higher yield.**
>
> CHRISTOPHER NEALE,
> DIRECTOR OF RESEARCH, DAUGHERTY WATER FOR FOOD GLOBAL INSTITUTE

Why, and how can this be improved? The researchers assessed whether deficit irrigation could be used to maximize water productivity under "an acceptable yield drop." Reducing irrigation

BOX 3

## AquaCrop-OS Workshop: Predicting a Better Future for Agriculture and Water Productivity

On the first day of the conference, nearly 30 researchers and students from around the world and from a variety of disciplines gathered to participate in the inaugural AquaCrop-OS workshop led by Tim Foster, lecturer in water-food security for the University of Manchester in the United Kingdom, with assistance from DWFI program associate Kate Gibson. Workshop participants learned about the development of AquaCrop-OS and familiarized themselves with the tool through practical exercises. AquaCrop-OS is a free and open-source version of AquaCrop, a crop water productivity model that was first developed by the Food and Agriculture Organization of the United Nations (FAO) in 2009.

"The main goal was to introduce participants to AquaCrop-OS, and help them develop the basic skills needed to apply the model to evaluate crop yield response to water and irrigation water management," said Foster.

The AquaCrop-OS model, launched in August 2016, was created by partners at the University of Manchester, DWFI, FAO, and Imperial College, London. It has been downloaded more than 300 times since its release. Learn more at aquacropos.com.

does indeed increase water productivity, but this response varies among different zones of the state. Therefore, one cannot suggest a general statewide strategy. The next step in the study will be to assess whether deficit irrigation to improve water productivity also will maximize net income. To do this, he said we must account for other inputs, as Scheierling suggested, and what Mekonnen called "multi-factor water productivity."

Christopher Neale, DWFI director of research, observed that while Scheierling discussed how difficult it is to use simple ratios to do comparisons, Grassini and Mekonnen showed that, in the same area, and in a specific context, we can use ratios for benchmarking. We can see who the high-end users are and then try to deliver educational information to them. According to Neale, saving water may not be the story; but if saving energy is a way to get farmers interested, we might show them the bottom line of reducing energy use and cost to get a higher yield.

The findings of this work, particularly the use of benchmarking and ratios to measure and compare water productivity, can be adapted to a wide range of other contexts — potentially helping us move from local to global impacts.

# TECHNOLOGICAL INNOVATION FOR INCREASED WATER PRODUCTIVITY

BHUSHIT AGARWAL

# Technological Innovation for Increased Water Productivity

*Archie C. Clutter, Dean of the Agricultural Research Division and Director of the Nebraska Agricultural Experiment Station within the University of Nebraska–Lincoln's Institute of Agriculture and Natural Resources*

Improving water management technologies is an important pathway to achieving water and food security. Conference participants discussed prospects for developing drought-tolerant crops through image-driven plant phenotyping, lessons from using cover crops to manage water in soils, and policy support for technological innovation.

## Developing Water Stress Tolerant Crops Through Image-driven Plant Phenotyping

Archie C. Clutter, dean of the Agricultural Research Division and director of the Nebraska Agricultural Experiment Station within the University of Nebraska–Lincoln's Institute of Agriculture and Natural Resources, explained that plant phenotyping is the science that quantifies plant traits to explore genotype-environment interactions. "High throughput phenotyping" is a tool designed to quantify morphological and biophysical traits and processes (e.g., water use efficiency) of a large number of plant genotypes to speed selection processes and breeding cycles. Improved plant water use efficiency can be achieved through better genotype selection, breeding and biotechnology. Because of its promise, the University of Nebraska is investing heavily in plant phenotyping technologies, labs, greenhouses and other equipment; the work involves more than 100

**Improved plant water use efficiency can be achieved through better genotype selection, breeding and biotechnology. Because of its promise, the University of Nebraska is investing heavily in plant phenotyping technologies, labs, greenhouses, and other equipment, and the work involves more than 100 tenured faculty.**

ARCHIE C. CLUTTER, DEAN OF THE AGRICULTURAL RESEARCH DIVISION AND DIRECTOR OF THE NEBRASKA AGRICULTURAL EXPERIMENT STATION

tenured faculty. Several presentations demonstrated the methodologies being developed and the potential for using these techniques.

Addie Thompson, a postdoctoral researcher at the Department of Agronomy, Purdue University, uses high-throughput genetics and phenomics to improve drought tolerance in crops. She set the scene by explaining the "Grand Challenge of Agriculture," doubling global food, feed, fiber and fuel production on existing farmland within the 21st century, under conditions of climate change. Her work focuses on developing varieties of target crops to improve adaptation to climate variability; for example, heat and drought tolerant maize, building on results from the Drought Tolerant Maize for Africa Project.

Ultimately, Thompson said, the goal is to identify unique regions of the genome that may be beneficial. To accelerate this process, researchers are moving into automated crop phenotyping platforms, initially with sorghum, but they plan to move on to other globally important crops. Many traits are now being counted more accurately, and statistical analysis is leading to better predictions, as well as, hopefully, better varieties. Thompson concluded that "automated phenotyping technologies based on airborne and ground-based sensor systems must be developed that will enable gene discovery and optimization of crop varieties and production systems for food production."

James Schnable, an assistant professor in the UNL Department of Agronomy and Horticulture and a DWFI Faculty Fellow, explained that grain crops vary in their efficiency at converting water into food, as do different varieties of corn and other crops. Plant breeding can enhance water use efficiency; however, traditional breeding cycles are long and increasingly expensive. The new approach he is working on will accelerate the breeding cycle and, therefore, reduce the costs. He explained the methodology and some of the technology that will be used in upcoming experiments. Both ground truthing and imaging data are collected; and, by

*Harkamal Walia, DWFI Faculty Fellow; Associate Professor, Department of Agronomy and Horticulture, University of Nebraska–Lincoln*

collaborating with people around country, they are generating additional data to build predictive models.

Plant molecular physiologist Harkamal Walia, an associate professor in the UNL Department of Agronomy and Horticulture and a DWFI Faculty Fellow, explained that the overall goal of his research is to discover genes and genetic variants that can be used to improve crop performance in suboptimal growing conditions. He is working on identifying the physiological and genetic basis of abiotic stress tolerance in plants; in this case, drought and salinity stress on rice. "What DNA changes drive responses is the key question." Walia's database is drawn from the "Rice Diversity Panel," which has about 400 diverse genotypes from 82 countries. The study found that several specific genomic loci regulate the responses of rice to increased salinity. Imaging brings out features that cannot be observed physically and show associations with genotypes and specific chromosomes. These findings are now being tested further.

*Yufeng Ge, DWFI Faculty Fellow; Assistant Professor, Biological Systems Engineering, University of Nebraska–Lincoln*

Advanced system sensing engineer Yufeng Ge, an assistant professor in the UNL Department of Biological Systems Engineering and DWFI Faculty Fellow, described an experiment on measuring evapotranspiration, water use efficiency and leaf water content in two maize genotypes, with two water treatments. The experiments were continuously monitored for 21 days using a hyperspectral camera, which can be used to predict leaf water content and calculate water use efficiency. Essentially, they found that water use efficiency is largely determined by genotype.

The work on high-throughput phenotyping is pioneering new techniques to speed up the process of breeding crop varieties that are drought-resistant or produce more grain per drop of water consumed. The new techniques are at an early stage, but hold great promise for the future — at both local and global scales.

## Keep it Covered: Lessons from Nebraska's Cover Crop Experience

Cover crops are used in the off-season for seasonal cover and conservation, as well as to create grazing land and forage for animal production. There are many potential uses, but the greatest benefits may be erosion reduction and aesthetics. However, as Roger Elmore, UNL professor of agronomy and extension cropping systems specialist, and a DWFI Faculty Fellow, explained, most cover crop studies have only minimal soil water content benefits. Nevertheless, there seems to be strong support in the notion that cover crops can be part of a solution for retaining moisture and improving yield. Elmore explained that recent studies at the University of Nebraska have adopted a new approach to cover crops, comparing Nebraska conditions with similar longitudinal climatic zones around the world. Positive results can then be scaled out to similar zones. The studies used Nebraska's Global Yield Gap and Water Productivity Atlas (yieldgap.org) to identify the global range of inference from Nebraska.

Humberto Blanco, UNL associate professor of agronomy and horticulture, described several recent studies designed to determine whether cover crops improve soil hydraulic properties, emphasizing that profit is the ultimate goal. "We can plant cover crops to offset various adverse effects, but there must be economic benefits or growers are not interested in doing it." Overall, while some cover crop benefits are seen in drier regions, Blanco said the team concluded there was not enough data to solidify benefits. "We need to get busy and do more work to get more data," he said.

Burdette Barker, a doctoral student in UNL Biological Systems Engineering, presented research on the impacts of winter cover crops on water content in maize and soybean cropping systems. He explained that Nebraska is well-suited for this research because it contains a wide variety of soils and conditions, from wet conditions in the east to primarily irrigated land in the western

half of the state. As in many other regions of the world, evapotranspiration is a perceived cost in Nebraska. "This study included a seven-way mix of rotated crops applied in four locations, with the same mix in two different planting times," Burdette explained. Burdette reported that cover cropping did not enhance soil water content, but he supported Blanco's conclusion that more data is needed.

> **Many things affect soil hydraulics. We can plant cover crops to offset adverse effects, but there must be economic benefits or growers are not interested in doing it.**
>
> HUMBERTO BLANCO, ASSOCIATE PROFESSOR OF AGRONOMY AND HORTICULTURE, UNL

Cody Creech, assistant professor and dryland cropping systems specialist at the Panhandle Research and Extension Center, UNL Department of Agronomy and Horticulture, talked about cover crop use in western Nebraska's harsh environment. "We are most interested in reduced soil erosion, because we get lots of wind," he said. However, he noted that "cover crops use water, and that can make it hard to establish a following crop, because the soil is very dry after the cover crop." Producers often have to wait until it rains to put in spring crops. Creech shared the results of recent studies that seem to discourage cover crop use. For example, one study showed wheat yield following cover cropping was on average 10 percent lower. In spite of these discouraging results, Creech and others are working on an upcoming grazing study, with a variety of systems of grazed, un-grazed, fallow and planted fields, to see if one system works better than another.

Overall, results from recent studies are mixed, and do not provide a firm basis for recommendations. More research is needed to understand the range of benefits and costs in specific contexts.

## Policies to Encourage Technological Innovation

A theme that pervaded the conference was the importance of policies that support effective markets, gender equality, investment in productive agricultural technologies and innovation. In a keynote address, Chandra Madramootoo, James McGill Professor in the Bioresource Engineering Department, McGill University, in Québec, Canada, developed the theme of using water policies to encourage technological innovation in irrigation. Madramootoo drew on experience in his home province of Alberta, Canada. He said irrigation has evolved in the province, and the market, combined with government policies, has driven changes in productivity. The province put a cap on water use by agriculture, leading to reduced irrigation diversions over time. Many more center pivots are used now, and water productivity has increased dramatically over the past 20 years, he said.

According to Madramootoo, improvements in technology could help Alberta farmers further reduce the amount of water needed to grow food. This might involve using different crop varieties, different inputs and improved mechanization. They will accomplish this, he said, in part through adopting precision irrigation. The province is now looking at how to scale this up to other irrigation districts, advising farmers how much water to apply, and encouraging them to use variable-rate technology to improve productivity.

But can these local lessons from Canada be applied globally? Madramootoo argued that many of the lessons learned in Alberta, such as moving from a supply-driven to demand driven irrigation scheme, can help in other water-stressed areas. In Pakistan and elsewhere, rotational water deliveries are based on supply, not demand. This often involves delivering water when farmers don't need it and having none available when they do need it. These farmers then resort to using groundwater, depleting the aquifer in many cases. Moving to demand-based surface water delivery can lead to more efficient water use.

Madramootoo emphasized the critical importance of building effective value chains in irrigated agriculture — an important theme of the sessions on African irrigation. Farmers in developing countries need to be given incentives to be more efficient irrigators. An effective value chain, he said, can put farmers into contact with markets, technology, credit access, advice on water and other benefits not necessarily linked to the government. The goal is for farmers to become linked to markets and adopt efficient irrigation technology.

> **The world's 500 million or so smallholder farmers currently have limited access to relevant information and market knowledge to increase profitability.**
>
> CHANDRA MADRAMOOTOO, JAMES MCGILL PROFESSOR, BIORESOURCE ENGINEERING DEPARTMENT, MCGILL UNIVERSITY


*Chandra Madramootoo, James McGill Professor, Bioresource Engineering Department, McGill University*

The world's 500 million or so smallholder farmers currently have limited access to relevant information and market knowledge to increase profitability. Madramootoo said digital technologies can link farmers to market inputs across the value chain. Farmers can use cell phones to get advice, access credit and gain other benefits. This will help them determine what crops are needed when, and better match what the market demands, as well as determine when to get the best value out of irrigation.

Can other countries learn from America's experiences addressing water scarcity? Ann Bartuska, Acting Under Secretary for Research, Education and Economics at the U.S. Department of Agriculture, told a plenary session about her department's work related to agriculture,

*Ann Bartuska, Acting Under Secretary for Research, Education and Economics, U.S. Department of Agriculture*

groundwater and water availability. She said her presentation was domestically focused, but the information can be applied around the world. According to Bartuska, the Green Revolution remarkably increased productivity — some five times for the major staple crops — with the same acres of land. She said, "We will continue to drive increasing production, while maintaining the same number of acres or less." This will involve different uses of the same acres.

She pointed out that 80 percent of U.S. water consumption is related to agriculture. One of the biggest challenges is increasing production with the same amount of land and using water in a way that doesn't undermine future use. Technological advances have helped, confirmed by the spread of center pivot irrigation in Nebraska and other places. Farmers have reduced water evaporation, and total water use is now fairly constant. "Irrigation withdrawals increased in the 50s-70s, [but] they are now flat to decreasing. Emerging technology allows us to do these good things," she said.

Bartuska noted that the 21st century will need to see a blue revolution for agriculture to sustain and increase production in the face of increasing population and drought, as was emphasized in the Africa sessions. She advocates a landscape-scale approach, involving such things as using alternative water sources, coordinating wastewater and irrigation systems, establishing crop breeding efforts for production under drought, increasing water use efficiency of irrigation systems, producing data linked with decision support tools, providing technical and financial assistance to promote

BOX 4

## Growing the World's Largest Agricultural Producer Databases: What's the Yield?

A special session highlighted students' experiences in the Design Studio program within the Jeffrey S. Raikes School of Computer Science and Management at UNL. The school recruits freshmen to the accelerated team-oriented computer science program, which is both academic and residential. It combines in-depth engineering and management training rooted in the real world. Junior and senior level students work on one-year Design Studio special projects, in which they build solutions with and for companies. Projects integrate engineering processes, lean business development and interdisciplinary design thinking. The focus is on delivering high-value products that are released to their clients for quick feedback, then adjusted to be more effective.

This discussion focused on a project implemented with DWFI to create an agricultural database to help producers, academic researchers and natural resources managers visualize and break down agricultural data to learn how to improve input efficiencies and increase profits.

The faculty and students described their experiences collecting and organizing large agricultural field-level data sets that can be used to improve field trial designs, reduce costs and monitor the impacts of new policies and technologies. The team collaborated with the Natural Resources Districts in Nebraska, gaining access to their vast amounts of data, to develop the online information portal. Nebraska is a "proof of concept" for the idea. As they proceeded, they discovered that the biggest challenge was to ensure that data are available in formats that can be used by different users – farmers, as well as scientists, for example.

For producers, they developed a color-coded scoring system that compares the producer to his peers – another example of benchmarking as a tool. Currently, the focus is on water and nitrogen use and efficiency. Scores with color codes and energy bars are used to compare the user to "efficient" and "average" producers. It is simple for a producer to add data, and the site is free and easy to use on mobile phones.

The next stage of the project will develop tools for NRD managers, and include additional data types, such as from remote sensing. A major point emerging during the discussion was the potential for collaboration with large companies, such as John Deere, which already is collecting a lot of Big Data.

adoption, and, at a government level, achieving interagency coordination.

Bartuska emphasized the importance of crop breeding and other new technologies, such as wireless sensor networks to control automatic irrigation scheduling — of which the relatively high efficiency was also emphasized by Grassini. Many programs provide technical and financial assistance to farmers, for example, to encourage conservation practices. Bartuska referred to a mobile phone app that allows farmers to check irrigation in the field, and talked about agricultural research and extension programs that put farmers together with scientists. "They are then testing for the particular question that is coming out of a real-time need," Bartuska explained. This may be an important lesson for Africa: speakers emphasized the important contributions of researcher-farmer collaboration. Stronger partnerships among African researchers and farmers could make a major difference.

# THE WATER GOVERNANCE CHALLENGE

JIMMY O'KEEFFE

# The Water Governance Challenge


*Nick Brozović, Director of Policy, DWFI*

Conference participants grappled with the difficult challenge of establishing effective and fair institutional arrangements for managing both large river basins and groundwater. Water governance includes the "political, social, economic and administrative systems in place that influence water's use and management. Essentially, who gets what water, when and how, and who has the right to water and related services and their benefits" (watergovernance.org). In many regions of the world, demand for water exceeds the available supply, a topic addressed in the sessions on water scarcity. This is increasing the potential for major conflicts, and leading to water resources degradation and depletion and water-dependent ecosystems destruction, and threatening billions of people's livelihood and well-being. Some of the technological and water management innovations discussed at the conference, such as breeding crop varieties that increase water productivity and improving irrigation methods, will be important to bring demand into line with supply.

Responding to these challenges requires effective institutional arrangements — water governance that works, is fair, and is seen to be fair. However, as emerged from many of the presentations, complex governance problems and the unique characteristics of different river systems and aquifers mean there are no universal solutions. Nevertheless, both the generic and case study presentations offered important insights, basic principles, and sometimes even practices that can be adapted and used in other contexts.

The governance sessions addressed three broad topics: sustainable and productive groundwater use; large river basin governance; and water markets as a potential solution to managing conflicting water demands.

## Governing Groundwater for Sustained Productive Use

"Groundwater governance is a hard thing to do well," said Nick Brozović, director of policy for DWFI. Groundwater is invisible, unlike surface water, but is an increasingly important water source for multiple purposes. Finding solutions for sustainably managing groundwater has become an urgent challenge. In most countries, groundwater is managed privately — farmers sink wells on their own land to tap what they perceive as "their" water. It is difficult to monitor individual groundwater use, and there is no consensus on how to define rights to groundwater, making it difficult to enforce limits on use. As Ruth Meinzen-

Dick from IFPRI explained, groundwater is a highly subtractive resource: what one person uses is not available to another person. "And it's hard to prevent others from using it," she explained.

***The global groundwater challenge.*** Groundwater services, benefits and functions include many different things: drinking water, tourism, industry, megacity water needs, ecosystems and fisheries. But "the giant use of water is food security," said Mohamed Bazza, senior water resources officer with the Land and Water Division of the Food and Agriculture Organization of the United Nations (FAO). "Seventy percent of groundwater is drawn for this." From 1960 to 2010, there was a 300-percent increase in groundwater abstractions globally.

> **The level of food security we have today involves going into the red, as if it was a savings account.**
>
> MOHAMED BAZZA, SENIOR WATER RESOURCES OFFICER, LAND AND WATER DIVISION, FAO

In many areas, groundwater levels are declining. The rate of pumping of aquifers exceeds the natural recharge rate. Further, pollution is reducing groundwater quality. Fourteen to 17 percent of global food production is now based on nonrenewable groundwater. "The level of food security we have today involves going into the red, as if it was a savings account," Bazza said. Five countries account for most of this deficit: India, China, U.S., Iran and Pakistan. On the other hand, with a few exceptions, Africa has yet to fully exploit its groundwater potential.

*Mohamed Bazza, Senior Water Resources Officer, Land and Water Division, FAO*

These threats to groundwater are largely a result of ineffective governance. Better groundwater governance is essential, as the world's population is expected to reach more than 9.5 billion by 2050, and food needs will increase 50 to 60 percent. To make matters worse, climate change will affect our ability to produce food.

Bazza introduced the main findings of a five-year project carried out on five continents, intended to pave the way to achieving effective groundwater governance. The project diagnosed the problem, and developed a shared global vision for 2030, as well as a framework for action to achieve the vision. The study proposes a "context-adaptable" overarching structure and processes for action consisting of five steps: 1) creating a basis for achieving good governance, based on a full understanding of the specific context; 2) building effective institutions, which will enable 3) creating the necessary linkages among the diverse sources of over-abstraction of groundwater. This will in turn provide a basis for 4) redirecting incentives and finance to encourage sustainable groundwater uses, and 5) using transparent and effective planning and management processes.

Three case studies from very diverse contexts — California, Brazil, and India — clearly demonstrated the enormous challenge posed by groundwater governance. They represent a

continuum from a relatively strong institutional capacity for regulation and enforcement, to one that is just emerging in Brazil, to weak capacity and often ineffective groundwater governance in India.

***California groundwater management reform.*** The California case can be seen as an application of FAO recommendations in a particular context. Christina Babbitt, manager of the California Groundwater Program through the Environmental Defense Fund (EDF), explained that EDF's Western U.S. program has a strong focus on integrated surface and groundwater management, getting water markets right and rewarding sustainable agricultural practices. "How can we stop using groundwater as an escape hatch?" is the question Babbitt said everyone is asking — or should ask.

According to Babbitt, groundwater meets 40 to 60 percent of demand. Until 2014, the state of California did not manage groundwater; local agencies had this responsibility. The historic 2014 Sustainable Groundwater Management Act (SGMA) created a requirement to transform groundwater management statewide, and provided new powers to local agencies. The legislation applies to basins containing more than 90 percent of the state's groundwater, and requires the creation of local agencies tasked with developing groundwater sustainability plans. These plans must rely on best management practices to bring groundwater supplies into balance and stop further depletion.

The state's timeline for achieving sustainability ends in 2042. Babbitt said local authorities responsible for developing groundwater management plans often do not have the necessary resources. This is one reason why the state is partnering with DWFI to put actions into place to manage groundwater challenges. "It's a real opportunity to learn," Babbitt said. EDF and DWFI are collaborating on nine case studies from Arizona, Texas, Nebraska and California to extract lessons for the future. While a one-size-fits-all approach is not the answer, in-depth case studies allow stakeholders to better understand and evaluate management approaches and their potential applicability. The study is examining four management tool categories: regulations, incentives, supply augmentation and protection, and education and outreach. The point is, she said, "when it comes to managing groundwater, we need to rely on a suite of tools."

**While a one-size-fits-all approach is not the answer, in-depth case studies allow stakeholders to better understand and evaluate management approaches and their potential applicability.**

According to Babbitt, the key requirements for successful groundwater management programs are:

Trust – Groundwater management often requires asking people to change what they do in a way that has a financial impact. People need to feel that the system is fair. This requirement emerged as a key lesson in other cases discussed at the conference as well.

Portfolio of approaches – Successful groundwater management programs are not achieved overnight, nor are they accomplished by a single regulation or policy. Multiple tools are necessary, and regulations should be added or updated gradually.

Assuring performance – This includes monitoring and enforcement supported by adequate financial and personnel resources and political, as well as community, support.

These requirements are consistent with the five steps proposed by Bazza, and were also reflected in the presentations on water markets at the conference.

*Christina Babbitt, Manager, California Groundwater Program, Environmental Defense Fund*

***Managing groundwater in Brazil.*** Marcos Heil Costa, a climate scientist with Brazil's Universidade Federal de Viçosa, gave an overview of groundwater management in his country. Costa said the country did not have a formal water policy until the 1988 constitution, while a 1997 federal law was the beginning of water governance. In effect, water is legally a public good with economic value, and management should be for multiple uses. Most aquifers are managed by states, except those that cut across state boundaries. But the institutional landscape is complex, with federal, state, river basin, watershed, local and other institutions involved. Brazil has a comprehensive national water resources information system, with two entities for groundwater: Integrated Network for Groundwater Monitoring, and Groundwater Information System.

Costa outlined some of the serious challenges facing Brazil. First, not all the designated committees have been formed. Few basins have actually implemented water use permitting and taxing arrangements. Other challenges include the lack of integrated surface and groundwater management, inadequate data despite recent efforts, and questions regarding the water management committees' legitimacy.

Clearly, Brazil is at an earlier stage than California, and, according to Costa, could benefit from applying some of the principles outlined by Bazza and Babbitt.

***An approach to groundwater management in India.*** Ruth Meinzen-Dick, from IFPRI, gave an overview of the groundwater challenges in India, then presented an innovative case study demonstrating the potential of experimental games to improve collective water management. Groundwater provides 60 percent of the water used for irrigation and 80 percent of India's drinking water. Increasing groundwater use is leading to serious aquifer overdrafts.

Responses to this situation must include a variety of tools, as also emphasized by Babbit and Bazza. Meinzen-Dick suggested that, with the rapid increase in pumping, traditional farmer knowledge is no longer sufficient to govern groundwater, while state regulation is largely ineffective. Therefore, water use reduction must be locally-driven, because there is limited external enforcement capacity. Meinzen-Dick said many people are trying to come up with ideas for what more could be done. "We are really talking about behavior change," she pointed out. Many people believe decreasing rainfall is causing declines in groundwater. "We've been working with communities to show them that, actually, groundwater does not come back when rainfall returns. We've used experimental games in small agricultural communities to affect behavior, not just study it."

Playing the game demonstrates to the players how the water supply can be depleted if everyone uses more water, even if they make more money by producing more food. As a game goes on, players tend to suddenly understand the issues and switch to lower-water-use crops. "It was a good learning event for the communities who participated," Meinzen-Dick said. "They said it was better than lectures and it helped them understand that their behavior affects groundwater, not just rainfall. They discovered the lessons, rather than being told."

While California and Brazil have the institutional capacity to solve their groundwater governance problems, in India, innovative approaches at the local level will be required in the absence of effective government regulation. Experimental games may be difficult to use on a large scale — but what about water markets as a solution?

## Water Markets: What Do We Know?

The U.S. Department of Agriculture (USDA), in partnership with NDMC, sponsored three sessions on water markets. The sessions were named "Water Frontiers," with a nod to the fact that this is a relatively new area of activity in water management. Until recently, water markets were largely informal, conducted on a handshake. However, formal agreements are increasingly being promoted.

The workshops explored market-based approaches to managing competing demands for water, as well as drought risk. Both conceptual considerations and case studies were presented and discussed. DWFI's Nick Brozović, said the goal was to "get a good understanding of markets and turn it into a primer — a roadmap the federal government can use to make things easier for those working in water and food issues." But highly divergent views emerged, as well. For example, while some presenters favor promoting formal, rule-driven transparent water markets, others pointed out the reality that most water transactions in the U.S. are informal and not transparent. With one exception, all the presentations were based on American experiences, but some of the basic principles can be adapted for application elsewhere. Many of the institutional requirements for effective water markets reflect the broader water governance principles discussed in other sessions.

> **"It was a good learning event for the communities who participated. They said it was better than lectures and it helped them understand that their behavior affects groundwater, not just rainfall. They discovered the lessons, rather than being told."**
>
> RUTH MEINZEN-DICK, SENIOR RESEARCH FELLOW, INTERNATIONAL FOOD POLICY RESEARCH INSTITUTE

***The promise of formal water markets.*** Christopher Hartley, an environmental markets analyst with the USDA, explained some of the basic challenges related to water rights and what he believes the government's role should be. Hartley argued water rights for specific bodies of water are similar to grazing, fishing or timber rights — in other words, these rights are revocable. The government is there to protect water and manage rights that cross jurisdictions. Water rights can be complicated by many things. For example, drought happens frequently, and has both immediate effects and long-term consequences. Another complication is that water users rarely pay the full value of water. And, as we have seen, groundwater over-withdrawal is a growing challenge.

Hartley said market-based solutions offer one of the best opportunities to manage water well. But, he admitted, "Most current market-based solutions are thin and have failed to achieve their potential." The USDA focuses on managing wetland and habitat markets, valued at about $6 billion annually. In 2015, active environmental water markets included buyback programs and groundwater offset programs in the western U.S. Hartley said the role of the USDA is to "make conditions right, so markets emerge naturally"— a point that reflects the lessons articulated by Bazza and Babbitt.


*Christopher Hartley, Deputy Director and Senior Environmental Analyst, Office of Environmental Markets, USDA*

Hartley believes governments should be responsible for developing policy, creating flexibility to allow markets to move forward, improving transparency, and reducing perceived risk and uncertainty. He said that the USDA and other departments can do four things to make markets more functional:

1. Promote water allocations that recognize the hydrologic realities. Water is over allocated. We need an accounting process.
2. Develop well-defined and tradable water rights and market structures.
3. Limit transaction costs. In most other markets, these costs are very high.
4. Continue investments in new water sources and water productivity, including wastewater treatment, desalinization, recycling and repurposing — there is no longer just single-use water.

Brozović dug further into the question of formal groundwater trading systems. "The point of water markets is to move water from low-value to high-value systems," he said. "There has been increasing interest in setting up transfer and trading systems for groundwater." But, as emphasized by other speakers, there must be clear objectives and an effective institutional framework, which starts with the ability and willingness to set and enforce rules, and proper oversight by an outside agent.

Brozović agrees with Babbitt of EDF in favoring a portfolio approach. He complemented Hartley's views and suggested three types of regulatory tools are needed for successful water market systems:

1. Regulations without financial incentives, such as moratoria on new wells, certification of acreage irrigated, metering of wells, quantified and allocated pumping rights, and stream augmentation projects.
2. Regulations with financial incentives, such as taxes, fees, surcharges, land retirement projects, recharge and depletion credits, and transferable permit systems.
3. Voluntary tools, such as education and outreach, which are often the most effective and inexpensive. Ruth Meinzen-Dick's presentation highlighted an example — using experimental games to change groundwater pumping behavior.

The regulatory framework is critical. "Are transfers legal? Quite often, the answer is we don't know," said Brozović. "We need to know this, especially as we move to a more formal system." As a formal water trading and transfer system is carved out, we need to ask many questions: Who are the buyers and sellers? Are transfers temporary or permanent? What are the implications for rights holders? Is


*Richael Young, Co-Founder and President, Mammoth Trading*

the process viewed as fair and trustworthy? Do transfers involve third parties, such as the county assessor or state and federal agencies?

Another critical aspect of setting up water markets is price discovery and the financial framework for transactions. This may involve professional brokerages, as well as other tools used for decades, such as coffee shop bulletin boards. Another essential requirement for healthy water markets is trust, as emphasized by Babbitt and other speakers. Building trust is hard to do; but "if you don't have that, it's harder to thicken a water market," Brozović said.

Monitoring and enforcement is the final pillar of a good water market trade and transfer system. Enforcement can be complicated, especially if fines have not been levied in the past. Well metering must be in place to make groundwater markets fair and effective, Brozović explained. In some states, less than a quarter of the wells are metered. This variation is a challenge to formal water trading systems. Unfortunately, he admitted, trading increases the incentive for misreporting. In one Nebraska case, a producer traded a water right, but then bypassed the flowmeter to keep pumping. The producer was caught, water rights were stripped from the land, and a multimillion-dollar fine was imposed. This kind of enforcement is necessary for water markets to work.

***The reality of informal water markets.*** Informal agricultural water trading is prevalent in the western U.S., as explained by Richael Young, from Mammoth Trading, a commercial water broker. Many of these trades take place under the radar, but the participants tend to be the largest water users in the nation. "Water markets are often presented as a solution to water scarcity," Young explained. "Headlines make it sound like a new

> **Water markets are often presented as a solution to water scarcity. Headlines make it sound like a new solution, but it's already happening. It's just happening informally.**
>
> RICHAEL YOUNG, CO-FOUNDER AND PRESIDENT, MAMMOTH TRADING

solution, but it's already been happening. It's just happening informally."

Young described some of the challenges water markets face. First, "the language used around water markets can be confusing, ambiguous, seemingly academic and detached from reality, or even polarizing." In addition, each of the western states has its own procedures and rules governing water markets. Even though agricultural water markets have been active for decades, Young said they have been informal and decentralized, so transactions are not recorded. Therefore, "we have no clue as to the extent market-based transactions are helping manage water."

Market structures, she said, are often simple handshake deals for small informal contracts and agreements. Opportunities are discovered and deals are made through brokerages and auctions, private real estate auctions, electronic bulletin boards, physical bulletin boards in communities and a small handful of electronic clearinghouses.

Third-party involvement can complicate water agreements. Third-party stakeholders may include irrigation districts, state water agencies, courts, county clerks (for public notices and deed transfers), title companies and brokers or aggregators. Water rights held by irrigation districts are different from privately-held rights. An irrigation district holds an official right to the water, normally bestowed by the state. Each district has many members that use that single water right with the same priority date. The members may transfer irrigation allotments among one another. Within a district, "There is no change in the water right itself," Young explained. "There is just a transfer within the same right. This provides a lot of flexibility private producers just don't have."

Finally, she pointed to the numerous obstacles to producer-to-producer water transfers. High search and transaction costs often mean only wealthy farmers can participate. "If we lower prices of transactions, smaller farmers can then participate," Young said, reflecting a point made by Brozović. Quantifying water rights is another obstacle, and regulating agencies have limited staffing and resources, combined with long approval processes. Finally, high risk with no guarantee is a serious problem. "You may not get the amount of water you need to justify the transaction," Young said. Essentially, the requirements for effective governance and formal water markets — trust, transparency, monitoring and enforcement — do not actually exist, even in the western U.S.

***Australia's experience with water markets.*** The Australian experience reflects many of the lessons learned in the U.S. and the principles articulated by Babbitt and Brozović, among others. However, the country's water stakeholders have followed a more comprehensive approach to reform than the U.S. Colin Chartres, Australian National University adjunct professor and director of master classes and training at the Crawford Fund, a national agricultural research advocacy organization, began with an overview of the Murray-Darling Basin (MDB) in southeastern Australia, the most important irrigated agricultural area in the country. He summarized the 140-year history and unintended outcomes of development and over-allocation of water. The basin closed in the 1990s,

*Colin Chartres, DWFI International Advisory Panel Member; Adjunct Professor, Australian National University; Director of Master Classes and Training, Crawford Fund*

leading to serious impacts on the environment and water quality, and a serious drought caused extreme hardship to irrigators. Numerous policy failings lay behind these problems. A "perfect storm" necessitated substantial reform, of which markets were only one part. Some reforms had begun in the 1990s; for example, the Murray-Darling Commission's cap on water flows and use.

In 2004, the drought precipitated action: federal and state governments committed to achieving sustainable water use in over-allocated water systems; introducing water rights registers and standards for water accounting; expanding water rights trading; improving pricing for water storage and delivery; and managing urban water demands better. Establishing functional water trading and markets was seen as the solution to many problems on "Australia's water reform journey." The package of solutions was complex and its implementation process involved multiple steps.

Chartres listed Australia's positive achievements. In the MDB, mature water markets are functioning and are used by irrigators, urban water authorities and the environment — about 30 percent of water allocated has been traded every year since 2007. Water entitlements are recognized as assets by banks for loans. There is evidence of greater efficiency in matters related to, as well as more resilience to, drought. For example, during the drought, water was traded to support higher-value perennial crops, and more irrigators survived the drought because they used the market to buy or sell water.

Knowing the value of water has encouraged innovation in irrigation system management, such as investments in new water delivery technologies, as is true in North America. "Water efficient farms make money," Chartres said. Because the market operates within a cap, there is greater environmental sustainability. The market provides a way to recover water for the environment through direct purchase from willing sellers and government investment in on-farm efficiencies using tender processes.

Chartres concluded by noting that "most people agree now that trading is successful." However, there are continuing concerns, including arguments over entitlement definitions, a recognition that some reforms were poorly sequenced, realization that subsidies of on-farm efficiency may not have been a good use of resources, and an understanding that "recent data do not substantiate increases in efficiency (crop per drop)." Clearly, Australian water markets are still a work in progress, but they reflect many of the principles deemed necessary by other speakers for formal water markets.

***Water markets in three states in the Western U.S.*** Three other case studies, from the states of Texas, Nebraska and Washington, demonstrated the complexity and context specificity of using water markets to share water. John C. Tracy, director of the Texas Water Resources Institute at Texas A&M University, reviewed the evolution of Texas water rights. Multiple institutions are involved for surface, ground, agricultural and municipal water. In many

areas, water demand exceeds supply. Curiously, water markets are not recognized formally as a strategy to close the gap, but five other tools are used for water management: municipal conservation, agricultural water conservation, water reuse, desalinization, and aquifer storage and recovery. Nevertheless, several types of water markets exist. Young noted there is no statewide water market in Texas, "but rather a collection of localized markets." These are limited in scope due to government regulations.

Kent Miller, general manager of the Twin Flats NRD in Nebraska, discussed groundwater markets on the Platte River. A moratorium on increasing the area irrigated by groundwater created the conditions for the emergence of water markets — similar to the Australian "cap and trade" approach. How do these markets work? Miller said that the district allows certified groundwater-irrigated acres to be transferred, but with conditions. A transfer cannot increase consumptive use. About 25-30 transfers occur annually, and water usually is transferred from less-productive to more-productive land.

Water rights can be separated from land rights in Texas, but there are many regulations governing this.

Mani Rouhi Rad, a post-doctoral scholar at the Yale School of Forestry and Environmental Studies, and his colleagues have studied the performance of Nebraska's water markets. They found that the number of trades increased over time, and that most trades occur within a five-mile radius, i.e., with neighbors. This suggests there is a high "search cost" limiting transactions among more distant people. Their analysis suggests that if there were no search frictions and people could trade with their "optimal partner," the benefit (to the seller) would increase by 40 percent. The study demonstrates the potential for markets to reallocate resources, but also that search frictions can be significant in these markets.

Michael Brady, assistant professor, School of Economic Sciences, Washington State University, said that his interest lies in the drivers of institutional change and reform. In 2015, the state of Washington experienced its first major drought in 10 years, which led to irrigation districts


*From left: Panelists Kent Miller, George Oamek and Kristiana Hansen discuss water markets at the "Water Frontiers III" session*

*From left: Robert B. Jacobson, Luna Bharati, Jerry Kenny and John (Jack) Schmidt at the session on water governance and management in great river basins*

launching smart markets for leasing water during droughts, another example of drought driving institutional change. He also noted the huge growth in the number of cabins being built in Washington, many of which use wells for their water supply. This has put pressure on the water supply and has led to several court cases over water rights. The courts essentially ruled that these residences have no water rights and the existing agricultural water rights cannot be used by houses, in essence discouraging the emergence of a water market.

The Nebraska Platte River and Australian cases, like the new California groundwater management law, illustrate two key principles: that crises often provide the motivation and opportunity to achieve radical reform; and that "cap and trade" policies limiting overall withdrawals of an aquifer or river, combined with creating a market for trading water rights, can achieve significant environmental goals in an economically profitable manner. The Washington state case demonstrated that laws also can discourage the emergence of water markets.

## Water Market Frontiers: Future Tools and Directions

***Lessons from agricultural carbon markets.*** Kate Zook, program analyst from the USDA Office of Environmental Markets, said we can draw lessons learned from setting up agricultural carbon markets. In theory, market efficiency will be achieved where there are clearly defined property rights and where transaction costs are low. Carbon markets have "missed the mark" on both parameters, and formal water quantity markets can learn from this experience. As is the case for water markets, transaction costs are a big issue. She emphasized a very critical cost involves developing the protocols – "the rule book for how markets are going to operate." Collecting the quantity and quality of data required, as well as monitoring and record keeping, are expensive. Negotiation costs are often very high, because brokers and lawyers become involved. Designing a project and getting everything documented and agreed to are costly activities, as is third-party verification.

Zook reviewed several solutions for reducing transaction costs, including creating models to facilitate the process of establishing agreements and aggregated risk pools — a solution often used for water environmental flow markets.

***Managing environmental financial risk.*** Institutional innovations for managing financial risks posed by the environment was the topic of a presentation by Gregory Characklis, Philip C. Singer Distinguished Professor at the University of North Carolina at Chapel Hill's Department of Environmental Science and Engineering. His focus is on environmental processes, such as drought, that pose significant risks to urban utilities, as well as irrigation districts. Variable and low revenues affect the ability of utilities to pay back loans. Noting that the World Economic Forum ranks water supply as being a very high risk, he observed that most environmental risks are not insured or otherwise hedged, and some are not managed at all.

Risks and losses are a function of natural, engineered and economic systems. Characklis' group carries out interdisciplinary research to identify sectors with linkages between environmental conditions (mostly hydrologic) and financial metrics, then models their interdependencies. They then characterize the financial risk (i.e., how severe the losses are and how often they occur) and develop tools and strategies to manage that risk.

Characklis stated that risk-based contracts are the least expensive solution. He outlined the advantages of index-based insurance over traditional insurance, which includes lower transaction costs (less subjectivity, no adjustors), fewer "moral hazard" concerns, and quick resolution of claims and payouts. However, developing an effective index is often difficult. The group found that rainfall-based indexes do not work well; the best option is a hybrid of an index based on drawdown flows and a drought surcharge.

Working in the Central Valley in California, Characklis found that there is a surprising similarity between urban utilities and irrigation districts with regard to risk management. Irrigation, the primary statewide water user, depends on surface water, but uses groundwater as a buffer during droughts. However, this is becoming very risky as aquifer levels decline and regulation increases. Further, a shortage of surface water also reduces hydroelectric generation. So, as farmers are pumping more groundwater, the cost of electricity is increasing. His team is developing more effective financial hedging tools, not only for managing irrigators' risks, but for managing risks faced by hydroelectric generating companies.

Characklis concluded with four lessons on managing environmental financial risk. First, it is important to identify those sectors with linkages between environmental conditions and financial metrics. Second, model the hydrologic, engineered

BOX 5

## New Tools and Data for Water Markets

Several speakers lamented the paucity of data on water markets. Christopher Hartley, USDA Office of the Chief Economist, presented a new tool for analyzing ecosystem services and markets for such services. EnviroAtlas is an online tool giving users the ability to view, analyze and download geospacial data and other resources. Linked to this tool is the Mapping Ecosystem Markets program, a collaborative partnership between USDA, the EnviroAtlas Platform of the Environmental Protection Agency and the Forest Trends' Ecosystem Marketplace. It is intended to improve access to geospatial information about environmental markets that will help federal agencies, private companies and land managers better understand market trends and patterns across the U.S. Hartley said the tool can be used for case studies, developing training materials and managing data.

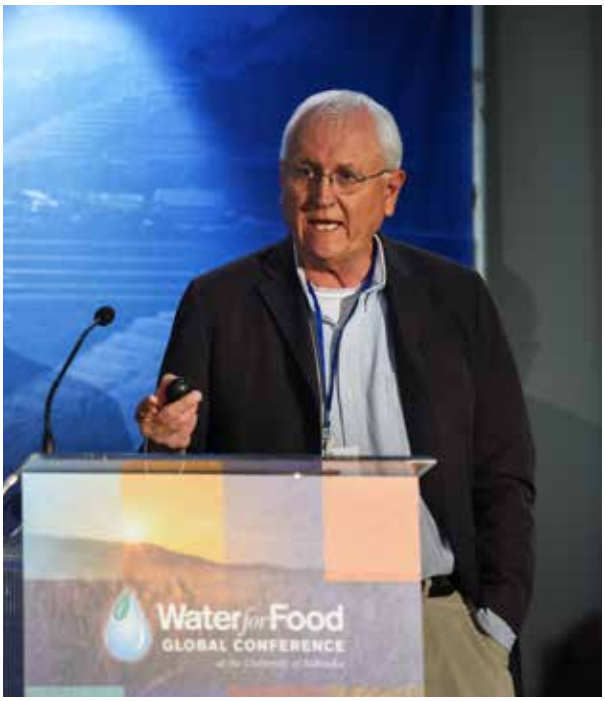
and economic systems as a coupled system, assessing their interdependencies. Third, quantify how severe the losses are and how often they occur. Fourth, develop new tools and strategies to manage that risk — and here he emphasized the important role of creativity and innovation. These principles are reflected in the approach to drought risk management in Africa presented by Tsegaye Tadesse. Hedging financial risks is likely to grow in importance in the future.

## Water Governance and Management of the Great River Basins

Two sessions focused on water quantity and quality and governance issues in five large river basins: the Ganges in South Asia, and the Colorado, Rio Grande, Missouri and Platte Rivers in North America. These basins face critical challenges in managing human water usage, and, more broadly: demand versus available supply, threats to water quality, and the need to balance agricultural and urban water requirements with conservation of water-based ecosystems. Climate change also is beginning to have major impacts; for example, increased incidences and severity of droughts and floods.

***The Ganges River Basin*** is an example of a major basin that lacks effective governance arrangements. Luna Bharati, principle scientist at IWMI, said the Ganges, with more than 500 million inhabitants, is the most populous river basin in the world. The river's resources are shared by China, Nepal, India and Bangladesh, and its water is used for agriculture, hydropower and other commercial enterprises, as well as urban water supply. The river also is known for its spiritual, religious and cultural significance. According to some scriptures, the river is a goddess. As Bharati explained, this emotional tie affects many decisions made about water in the region.

There is seemingly plenty of water for everyone in the Ganges basin, but the water is distributed




*John (Jack) Schmidt, Professor, Department of Watershed Sciences, Utah State University*

unequally, both temporally and spatially. Most rain falls during the summer monsoon season. During other periods, the region must deal with low precipitation and low flows. Further, there is a lot of inter-annual variability, and the spatial distribution of water supply and demand do not match. The mountain region is where precipitation and water yield is the highest, while demand is highest in the plains. From a management perspective, this temporal and spatial variability is the main challenge — as is the case with the Colorado River in North America.

Other challenges in the Ganges Valley, lack of development makes people vulnerable to climate change disruptions. Groundwater is a critical, but scarce resource, with many competing demands and no comprehensive water governance system. In addition, the Ganges River water is highly polluted from multiple sources: urban, industrial and agricultural pollution, along with widespread open defecation.

Agriculture uses more than 80 percent of the Ganges water. Water and land productivity vary spatially, but on average are low. There is a direct link between low productivity and the high levels of poverty in the basin: Nepal and the eastern portions of the basin are poverty hotspots. The basin's hydropower potential is very high, but unevenly distributed and poorly developed. Bharati said the region's countries have a discussion every year about hydropower generation, but they go back home and nothing happens because of mistrust.

Most of the challenges faced by the basin begin with institutional issues at local, national and international levels. Water management institutions are fragmented at all levels. And transboundary relations are "a mess," according to Bharati. Cooperation is strained, with mistrust, lack of cooperation and data sharing, and no large basin authority — but there is a lot of water in the basin.

> **The tough battles are [with] water supply, and we just don't take those on. River ecosystems can't be ignored.**
>
> JOHN (JACK) SCHMIDT, PROFESSOR, DEPARTMENT OF WATERSHED SCIENCES, UTAH STATE UNIVERSITY

***The Colorado River Basin*** in North America also poses incredibly complex challenges. This was reflected in the number and diversity of presentations. The fundamental challenge is to reconcile the competing demands of agriculture, urban areas and ecosystems. Compared to the Ganges, institutional arrangements for addressing these challenges in the Colorado River Basin are stronger, but, like the Ganges, fragmented among localities, states, the federal government, and courts.

John (Jack) Schmidt, a professor in the Department of Watershed Sciences at Utah State University, and Bradley Udall, senior water and climate scientist and scholar at the Colorado Water Institute, Colorado State University, described the history of Colorado River Basin development. Agriculture is the biggest water user on the Colorado River, and was also the earliest user. In the upper basin states, 90 percent of the water used for agriculture goes to alfalfa and pasture. In contrast, the lower basin states use water to grow a wide range of high value crops year-round.

Mexico, along with seven American states, hold specific rights to the Colorado's water — and much of it is used downstream. Because of the high level of water use, both the Colorado and the nearby Rio Grande River include "dewatered" segments downstream. In both rivers, ecosystem restoration will require water savings from agriculture to be reallocated. But there is no political consensus to do anything about this, according to Robert B. Jacobson, research hydrologist at the U.S. Geological Survey's Columbia Environmental Research Center.

Upstream, where water is relatively plentiful, Jacobson said the concern is the effect of large dams and reservoirs on downstream ecosystems. These effects are caused by both the existence of the dams and operational decisions on releasing water. The dams trap sediment, while erosion occurs downstream of the dams. This has changed both flow regimes and water flow temperatures, in turn leading to major changes in aquatic life, with some indigenous species being threatened, while undesirable species thrive. "We spend millions of dollars trying to fix all of this," Jacobson said. "And there is a high economic cost for controlling flooding. In the [ecosystem] releases, some water is wasted — it's not producing electricity. So, every flood has a dollar cost in lost potential."

While demand for water is continuing to grow, there is a long-term downward trend in runoff. Udall said, from 2000 to 2014, Colorado River flow reductions averaged 19.3 percent annually.

"By midcentury, at these rates, we could lose 20 percent of flow in temperature-induced declines and 35 percent by the end of the century," he said There is no evidence precipitation will increase again. Schmidt asked, "Can river ecosystems be rehabilitated with declining runoff?" He suggested impending decreases in runoff may force reconsideration of agreements on how to distribute the water supply. To date, negotiations on redistributing the supply have not considered the effects on river ecosystems, but these will have to be considered in the future. He concluded, "The tough battles are [with] water supply, and we just don't take those on. River ecosystems can't be ignored."

Udall focused on connecting water governance with "real live actions" in agriculture; i.e., how to provide water to growing cities and the environment without "buy and dry" impacts on agricultural land. Since 1968, Phoenix and Tucson have received water from the basin through the Central Arizona Project. "It's one of the reasons this basin is under stress," Udall said. "It proves the old adage that water flows uphill toward money." He said this project created the structural deficit in the basin.

Udall reviewed ways water is being conserved by farmers in the basin: deficit irrigation, rotational fallowing, crop switching, and irrigation efficiency and water conservation. But all of these have limitations and none is a panacea. For example, terms like "irrigation efficiency" and "water conservation" may have positive connotations, but they are actually quite complex and often problematic, as other conference speakers also noted. Increasing irrigation efficiency means savings in nonconsumptive use water, but this usually impacts another user via return flows.

Experiences in the Colorado River Basin offer lessons for other river basins. "The Colorado River Basin is at the forefront of the stresses of population growth and water stress, including climate change and increasing aridity through drought," Udall said. He concluded by emphasizing that it takes municipalities, NGOs and producers all working together to make these things happen.

> **The number one gambler in Alabama is the farmer who bets everything he has on the hope that it will rain at the right time.**
>
> JOHN CHRISTY, DIRECTOR, EARTH SYSTEM SCIENCE CENTER, UNIVERSITY OF ALABAMA IN HUNTSVILLE

***The Platte and Missouri river basins.*** Balancing ecosystem restoration and other uses of water, including agriculture, was the subject of presentations on the Platte River in Nebraska, a tributary of the Missouri River, and the Missouri River itself. These rivers have overdevelopment in common with other North American rivers, which has led to serious degradation of water-based ecosystems. Here, in contrast with the Colorado and Ganges basins, the major driving force is environmental. Solutions being tried are different from those in the Colorado basin; for example, there is less emphasis on reserving water for farms, and more emphasis on meeting environmental needs.

Jerry Kenny, executive director of the Platte River Recovery Implementation Program (PRRIP), said PRRIP is a unique collaborative program involving the federal government and Colorado, Wyoming and Nebraska, designed to achieve compliance with the Endangered Species Act. The goal of PRRIP is to develop a shared approach for managing the Platte River to protect habitats and balance their needs with the needs of water users — mainly farmers. The program implements science-based activities aimed at land and water rehabilitation for three endangered bird species.


*John Christy, Director, Earth System Science Center, University of Alabama in Huntsville*

There are several advisory committees associated with the program. Key among them is the independent science advisory committee. Kenny said "a lot of money is being spent on the science side. The science has to be credible and trusted by all." The program contains three major components: the Land Plan, the Water Plan and the Adaptive Management Plan.

The Land Plan aims to acquire, protect and restore 10,000 acres of habitat for three target bird species. Kenny said this goal has been surpassed, with 12,000 acres protected. The Water Plan goal is to reduce deficits to U.S. Fish and Wildlife Service (FWS) target flows by an average 130,000 to 250,000 acre-feet per year. So far, all but 90,000 acre-feet per year has been achieved. The Adaptive Management Plan is the most innovative component. It provides a way for the program to move forward in the face of uncertainty. "It allows you to learn by doing and answer questions as you move along," Kenny said. "You can't wait until you know everything you need to know. You have to plunge in and start doing things, but it's a very rigorous, methodical process."

While the PRIPP program faces challenges, Kenny is optimistic, based on preliminary analysis of the endangered species with and without the program. He said the cost of creating the habitat is half of what it would be without the program. A major effort is focused on building trust. As Kenny put it, there is "no substitute for relationship building when it comes to changing the culture." The Missouri River is a tributary of the Mississippi River and runs through 10 states. The basin affects 28 native tribes and 10 million people who depend on it for a variety of water resources, including hydroelectric power, navigation, flood control, urban water supply (e.g., for Denver, Colorado), Kansas aquifer recharge, recreation and ecosystems.

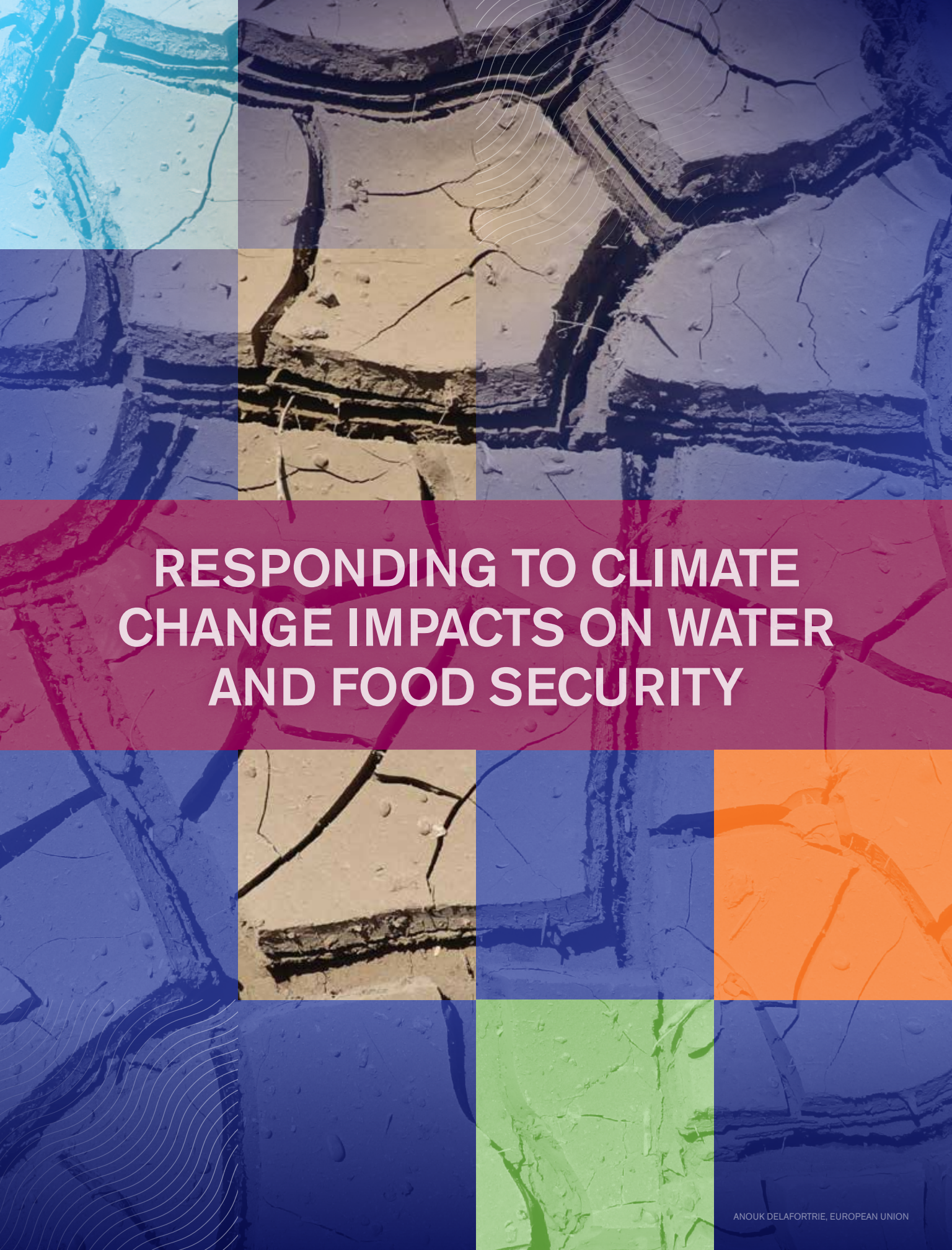
*Missouri River, USA*

Robert B. Jacobson of the U.S. Geological Survey, described efforts to restore ecosystem services on the Missouri River. "The wide range of opinions about the river is partly because things are different in different places," Jacobson said. Like the Colorado and Platte Rivers, the Missouri faces multiple challenges, including hydrological changes because of sedimentation and channelization, and agricultural and industrial pollution.

The U.S. Corps of Engineers is responsible for managing the river and maintaining its infrastructure and services, but, as is the case for the Platte, the Endangered Species Act is the driving force to restore the natural variability of river flows. The most intense conflict originates with those who oppose downstream floodplain agricultural interests and have a strong interest in ecological restoration.

Differences of opinion about restoring the river flows' natural variability is the most difficult conflict to overcome. "We need spring pulses for sandbar building, spawning, floodplain connectivity and low-flow for sturgeon," Jacobson said. "But low-flow, for example, would be a threat to navigation." The question is whether it is possible for the floodplain agricultural community to benefit from ecological restoration and enhanced ecosystem services. The anticipated ecological gains are uncertain, while the economic losses from restoration — represented by about 11 million metric tons of corn production — are perceived as a definite outcome. This is a difficult threshold to cross.

In conclusion, Jacobson said, "Objectives are highly divergent, so conflicts are acute. The potential is win-win, but not as great as we thought. Two potential win-win solutions — flood risk reduction and nutrient mitigation — produce marginal results, and "are not slam dunks." Hope for defining common ground between ecological restoration and floodplain agriculture may depend on quantifying a wider range of ecosystem services: recreation, hunting leases and alternative crops.



# RESPONDING TO CLIMATE CHANGE IMPACTS ON WATER AND FOOD SECURITY

ANOUK DELAFORTRIE, EUROPEAN UNION

# Responding to Climate Change Impacts on Water and Food Security

Growing concerns related to likely impacts of climate change on the availability of water and on food security permeated many conference sessions. But several presentations specifically focused on responding to climate change impacts in Africa, Nebraska, Latin America and the Caribbean. Improving our knowledge of climate-induced changes will help farmers and others adapt and become more resilient to shocks.

The Greater Horn of Africa is "one of the most vulnerable regions to current climate variability and potential future changes," according to NDMC's Tsegaye Tadesse. The economies and people's livelihood heavily rely on rain-dependent agricultural, agro-pastoral and pastoral systems. Changes in the frequency and intensity of precipitation potentially will have even more devastating impacts, amplified by "non-climatic stressors" such as political instability, war and migration. For much of this area, the potential to increase irrigation is small.

Therefore, it is critically important to develop and implement adaptation strategies to strengthen the resilience of vulnerable communities. This requires accurate information on possible changes in climate extremes, the aim of the NASA-Greater Horn of Africa Project. Local experts from eight of the nine countries in the region are participating. The project uses participatory research to bridge the gap between scientific knowledge and experiential or local knowledge. The goal is to find ways to integrate and involve stakeholders in the process, using a variety of participatory tools, such as webinars, interviews, focus groups, surveys and workshops.

Tadesse concluded that, "the evaluation and improvement of these models could help improve the crop models and therefore improve planning and food security." More importantly, they build confidence in changing the behavior of policymakers, extension agents and farmers. In essence, "a better understanding of changes in weather and climate extremes is essential to manage climate-related risks to humans, ecosystems and infrastructure, and develop resilience through adaptation strategies."

> **"[B]etter understanding of changes in weather and climate extremes is essential to manage climate-related risks to humans, ecosystems and infrastructure and develop resilience through adaptation strategies."**
>
> TSEGAYE TADESSE, ASSOCIATE PROFESSOR, UNL SCHOOL OF NATURAL RESOURCES, AND CLIMATOLOGIST, NATIONAL DROUGHT MITIGATION CENTER

Nebraska experiences greater climate variability than most of the U.S. Both Nebraska and the nation are seeing a gradual upward climb in temperatures. Martha Shulski, Nebraska's state climatologist and director of the Nebraska State Climate Office, as well as associate professor in the UNL School of Natural Resources, said the length of the frost-free season has increased by about a week in the Great Plains. She shared other

*Martha Shulski, Nebraska State Climatologist; Director, Nebraska State Climate Office; Applied Climate Science Mission Area Leader; School of Natural Resources, University of Nebraska–Lincoln*

important insights on climate change impacts in the U.S., shown in Table 1.

How will these climate trends affect farmers? Shulski said there is a wide variety of possible effects that could be of interest to agricultural producers. Warmer wetter winters, for example, could result in greater survivability of pests and could affect farmers' ability to get into the fields with equipment.

In other areas of the world, Shulski said, changing climate might produce a longer freeze season. She also foresees increased competition for water resources around the globe, which could impact climate-related decisions for farming. "Competition for water will involve municipal, recreational, cultural and other demands," she said. "All of these things will be of a greater magnitude in the future — they will exceed the magnitude of our experiences in the last century."

TABLE 1

**Table 1. Key Issues and Impacts of Climate Change for Nebraska and Beyond**

| | |
|---|---|
| Warmer and wetter winters, fewer extreme cold events. | Pest and disease shifts, survivability. |
| Warmer and wetter springs. | Potential loss of fieldwork days. |
| Longer freeze-free season. | Shifting timeframe for planting cover crops. |
| Drier and hotter during summer. | Soil moisture benefits from cover crops. |
| Increased competition for water resources | Less agriculture water availability. |
| More extremes (heat, drought, heavy downpours). | Impacts could vary depending on timing. |

*Source: Shulski Slide 13*

## Water for Agriculture in Latin America and the Caribbean Under a Changing Climate

Latin America and the Caribbean are also potentially at severe risk due to future climate change, with possible increases in extreme climate events, such as flooding rains, damaging winds, drought, heat waves, and, in high elevation mountainous regions, excessive snowfalls. However, there are currently gaps in our knowledge about enabling dynamical downscaling. Also, the complex topography of these areas and their nearness to oceans make developing useful predictive models a challenge. Robert Oglesby, UNL climate modeling professor and a DWFI Faculty Fellow, said that to properly simulate both mean climate and extreme events, a higher spatial resolution (four km) is needed in mountain areas, while a coarser resolution (12 km) is adequate where there is not much topographical relief. Modeling work done in Bolivia by Azar Abadi, a PhD student in the UNL Department of Earth and Atmospheric Sciences, confirms this finding.

Alfred Grunwaldt, climate change senior specialist at the Inter-American Development Bank (IDB), explained that climate change is a threat to achieving the SDGs. Therefore, IDB is trying to mainstream climate change information into its development programs. It plans to increase climate change financing to 30 percent of the total portfolio by 2020. This is consistent with the plans of other international and regional banks, such as the Asian Development Bank, African Development Bank and the World Bank. Much of this work is being done as part of a cooperative project with UNL, which is building tools and strengthening local capacities to better understand the nature and extent of climate change impacts. UNL has worked with IDB to produce IDB's knowledge platform for adaptation to climate change, in Spanish.


*Children in areas hit by floods in Peru*


*From left: Juan Jose Nieto, Caspar Ammann, Tsegaye Tadesse and Azar Abadi in the session discussing climate change impacts on water and agriculture*

Caspar Ammann, from the Climate Science and Applications Division of the National Center for Atmospheric Research in Boulder, Colorado, offered a detailed example of an Andean Development Project aimed at strengthening the local economy and livelihoods. The problems facing the locale were a lack of consistent water supply, a need to supply growing municipal and industrial water demands, and a need to develop commercial-scale agriculture. The study was intended to identify and evaluate options for bringing water into the area based on an understanding of likely climate change impacts. He explained the "Climate Risk Management engine" (CRMe), which can be used to convert and display climate variables into a variety of climate indices.

Juan José Nieto, from the International Research Center on El Niño (CIIFEN), summarized work on the Jubones River Basin in Ecuador. Climate models generally agree on trends in temperature change, but, Nieto said, "Precipitation models do not agree at all." Nevertheless, the models are indicative: less precipitation in the future will lead to greater vulnerability to food insecurity. His project involved national institutions and a consortium of autonomous local governments committed to developing adaptation measures. He outlined several lessons learned from this project: Information should be disseminated using multiple mediums to reach a variety of audiences, climate change and its possible impacts must be communicated in a way that's easily understood by the potentially affected sectors, and the possible adaptation measures should include local knowledge and culture.

Clearly, climate change impacts and the implications for water and food security vary considerably. The climate specialists at the conference agreed we need to do a better job of clearly communicating scientific forecasts of climate change so policymakers, farmers and others can make informed decisions.


Water for Food
DAUGHERTY GLOBAL INSTITUTE
at the University of Nebraska

# THE VIEW FROM THE FIELD

# The View from the Field

*From left: Celestino Zanella, Leon Kriesel, Brant Burkey and Danny Merkley at the "View from the Field" session*

A special conference session gave farmers from Nebraska, California and Brazil an opportunity to share their experiences on water management practices in agriculture. The four farmers described their experiences with water and food, as well as making observations on the conference itself. The moderator, Ron Yoder, associate vice chancellor, UNL Biological Systems Engineering, explained that sharing agricultural knowledge of the Great Plains region was a part of DWFI's founding purpose.

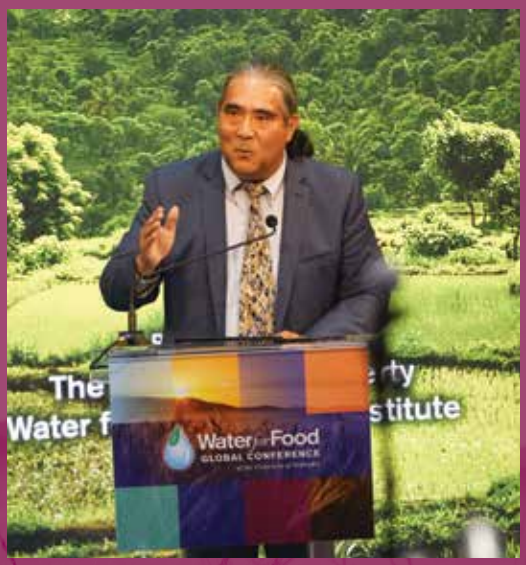
Brent Burkey, a farmer from eastern Nebraska, shared that he sees a lot of the problems discussed at the conference on a local scale. He said one of the things farmers are seeking is advice about data and what it means globally, as well as how it can be applied locally. "Data is a blessing and a curse," he said. "And you [conference attendees] can potentially be a part of the solution." He explained the paradox: farmers need more data, but are getting swamped with data. According to Burkey, the solution is to "insert the solution within the workflow of the farmer. "We can't be distracted with other things when we need to be in the field." In conclusion, Burkey said, "Tools are great, but solutions are better."

Another Nebraskan farmer, Leon Kriesel, explained that farmers in the dry western part of Nebraska have become very water-conservation

oriented. For example, they have changed from fallow systems to more of a no-till system. About 85 percent of the ground is no-till, he said, which saves water. "It works, but there are consequences," he said, including weed issues and problems managing runoff.

Danny Merkley, director of Water Resources for the California Farm Bureau, addressed the recent drought affecting California agriculture and some of the farmers' responses. He observed that the drought's economic impacts were high — not only on agriculture, but the broader economy. More than 10,000 agricultural jobs were lost, and an additional 21,000 people lost their jobs in other sectors. Farmers and ranchers have responded by fallowing land — some 542,000 acres in 2015. Merkley explained, "It's not really voluntary. It's drying up and taking it out of production." Further, mirroring Alberta, Canada, and other experiences, they have adopted more efficient irrigation systems. Crop production per acre-foot of applied water has increased over 43 percent since 1967. Finally, Merkley said the new groundwater management act will dry up a lot more agricultural land. He concluded by expressing his skepticism about recent proposals to increase environmental flows in rivers, suggesting the cost in lost agricultural production is not worth the small environmental benefits.

Celestino Zanella, a farmer and president of the Association of Farmers and Irrigators of Bahia (AIBA) in Brazil, said that AIBA, a nonprofit organization founded in 1990, was created "to make the agricultural sector more competitive through joint cooperation between municipal, state and federal government entities in the areas of infrastructure, logistics, warehousing, energy and research." Its members include more than 1,300 farmers and organizations linked to the agricultural sector. The state of Bahia is about the same size as Nebraska, but farmers produce more. Association members supply and finance many services that in the U.S. are provided by the government. For example, AIBA farmers repair roads with equipment belonging to the association, and they




*A.G. Kawamura, founding co-chair, Solutions from the Land*

## Closing Plenary and Heuermann Lecture

Arthur Gen "A.G." Kawamura, founding co-chair of Solutions from the Land and former California Secretary of Agriculture, closed the conference by addressing how creating abundant water, food and energy systems forms the framework for a thriving world. Kawamura emphasized that our past collective human experience can help us understand where we've been in terms of our food production systems, but that our focus must lie on the new thinking and vision required to embrace the future. He urged society not allow "deferred maintenance" or conflict to delay the agricultural renaissance ahead. To achieve the UN Sustainable Development Goals, "it becomes incumbent on us in agriculture to lead the way," said Kawamura. He urged the audience to adopt a collaborative, solution-oriented approach to our agricultural endeavors. "Successful agriculture sustains civilization," he stated. "Let's roll up our sleeves and get to work. We've got a lot of work to do before the year 2030."

BOX 6

## Together We Make Water a Global Priority

Dale Jacobson, a member of the World Water Council Board of Governors, gave a luncheon presentation on the work of the World Water Council and its triannual World Water Forum. The council is an international, multi-stakeholder organization with 300 members that represent organizations from more than 50 countries. Its mission is to "mobilize action on critical water issues at all levels, including the highest decision-making level, by engaging people in debate and challenging conventional thinking."

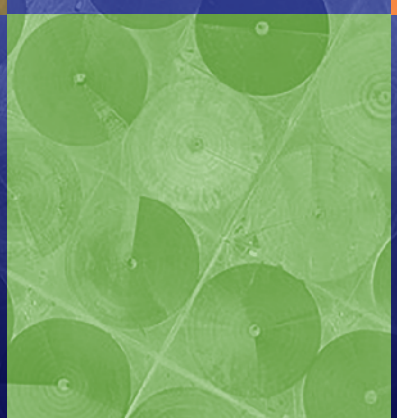
The World Water Forum, as the world's largest water-related event, is designed to challenge thinking and engage debate. The eighth World Water Forum will take place in Brasília, Brazil, in March 2018. Its main theme will be "Sharing Water." Jacobson said meeting schedules and topics can be found on the website: www.worldwatercouncil.org. DWFI will participate in this forum in 2018 in lieu of hosting its global conference.

perform other social services, such as firefighting, supporting about 100 police officers, and running social programs.

Zanella said in Brazil there is a huge potential for increasing irrigated production without environmental problems. Nebraska is a good place to learn about agriculture and take it back to Brazil, he said. "We can send people here, and you can go to our regions, and it will help everybody."

In the panel discussion, the two Nebraskan farmers agreed that more education is needed to develop more reasonable policies. But Merkley was more skeptical. He said that in California, "we have enough water; we just manage it poorly." He said state infrastructure has not kept up with the increased population and environmental demands. All four of them agreed that farmers are rational people and can solve most problems themselves if urban policymakers do not impose unreasonable rules. Yoder concluded that we are all in this together. It's not entirely accurate to say agriculture uses too much water. It's the people who eat the food who ultimately use the water. One of the panelists commented, "In agriculture, we are experts at circling the wagons and shooting at ourselves."

# CONCLUSION



# Conclusion

*From left: Michael Boehm, Giovanni Piccinni, Marcos Folegatti and Margaret Catley-Carlson provide closing thoughts*

The conference concluded with a wide-ranging panel discussion sprinkled with inputs from the floor. In opening remarks, outgoing chair of the DWFI Jeff Raikes reiterated, "We have a huge challenge, but the people at this conference have the power to achieve water and food security." He set an optimistic tone to the conference proceedings: the glass is half full. He said we have the means to combine science with local practical experiences to find solutions and achieve water and food security for everyone, and reminded us that global change begins at home.

Some of the closing panelists were more optimistic than others. The University of Nebraska's Michael Boehm said his is a "glass half empty view," referring to the vicious cycle drought creates through lack of food, poverty, and stunting. He observed that 1 billion people in the world live in abject poverty. In fact, he said, 13.4 percent of Nebraskans don't know where their next meal is coming from. In the U.S. overall, it's 14.6 percent. How can a state produce so much food, and have so much food insecurity, he asked?

But other panelists were optimistic. Margaret Catley-Carlson, vice chair, Canadian Water Network, and a member of the DWFI International Advisory Panel, asked whether we can realistically achieve a move from local to global lessons. The answer, she said, is yes and no. "There were great sessions on water markets with great case studies. Water markets are a great and useful tool, but there are no prescriptions. The conditions have to

be right." She said there is solid agreement on the basic principles of creating the proper conditions for markets, "so maybe that is what goes global: not the cooked plan, but the ingredients."

Each session of the conference demonstrated, when examined in depth, the challenges of achieving water and food security for all are enormously complex. This is as true for understanding how to promote irrigation as an effective intervention in Africa, as it is for how farmers can simultaneously produce more food with less water and "save" water for allocation to other uses, or how to design effective and equitable water governance systems. There are no simple one-size-fits-all solutions that can be applied everywhere. The details of local context matter a great deal, and attempts to make improvements must not only be adapted to that context, but be accepted and driven by the local stakeholders themselves.

However, in spite of the challenges, we can learn by analyzing a variety of case studies and extracting basic lessons and principles. For example, in Africa, irrigation can be expanded only if it is profitable and sustainable, regardless of available technology. Therefore, effective policies, information sharing and capacity strengthening aimed at creating effective value chains are prerequisites for success. The Australia, Nebraska, California and Alberta, Canada, cases demonstrated that, with the right policies, farmers will adopt new irrigation technologies that maintain their profits while reducing water consumption, thus potentially making water available for other uses, including the environment. Water markets can be a large part of the solution in many different contexts, if the basic foundations are laid.

This seemed to reflect the views of many participants. Roberto Lenton, DWFI's founding executive director, commented that when people are listening to sessions on experiences in various parts of the world, they are always connecting them to their own context, and that is what makes the conference meaningful. People listen, then interpret and think about what it means in their own context. Boehm said we are on the right track. The conference exposes us to diverse perspectives, which is critical, he said. "We need to think globally and act locally. We need local teams committed to a common shared vision, not acting in lockstep, but being clear about where we're going," Boehm added.

Participants also learned about new cutting-edge technologies and institutional solutions for water scarcity. Examples included the sessions on using advanced automated phenotyping techniques to speed up the search for crop genes that require less water or are drought- or salt-resistant, and new modeling techniques to better forecast the impacts of climate change in regions like Latin America, with diverse topographies. Some presentations shed light on research areas that so far have not been well exploited; for example, using hedging tools to manage exposure to financial risks for urban water utilities and irrigation districts associated with drought, and the interdisciplinary "Design Studio" approach to making large agricultural data sets available to multiple users.

DWFI Executive Director Peter G. McCornick concluded the conference by saying we are going away with new resolve and new ideas about solutions. "Getting the story out to the right people is important," he said. "It's so complicated; it's difficult to get the right message out there about the ways we can have meaningful impact."

"As a concerned, connected community of stakeholders, we need to agree on a compelling story about the world's relationship to and responsibility for water and food," he said. "So we can challenge and inspire decision-makers to implement 'super audacious and bold solutions' for water and food security."

---

*Full presentations from the conference are available on our YouTube channel.*
**youtube.com/WaterForFood**

# Appendix

WORKSHOPS, EVENTS AND PRESENTATIONS

## MONDAY, APRIL 10

### Technical Workshops and Seminars

#### AQUACROP-OS WORKSHOP: PREDICTING A BETTER FUTURE FOR AGRICULTURE AND WATER PRODUCTIVITY (By Invitation)

This workshop introduced invited participants to the key concepts of AquaCrop-OS, a new open-source crop-water simulation model developed by researchers at the Daugherty Water for Food Global Institute, the University of Manchester, Food and Agriculture Organization of the United Nations and Imperial College London. Participants gained hands-on experience using the model through a range of practical exercises.

**SPEAKERS:**

**Tim Foster,** Lecturer in Water-Food Security, University of Manchester; United Kingdom

**Kate Gibson,** Program Coordinator, Daugherty Water for Food Global Institute; Lincoln, Nebraska

#### WATER APPLICATION INNOVATION CONSORTIUM: STRATEGIC COLLABORATIVE PARTNERSHIPS DEVELOPING NEW SYNERGIES TO CREATE INNOVATION IN AGRICULTURE AND LANDSCAPE WATER PRODUCTIVITY (By Invitation)

The Foundation for Food and Agriculture Research (FFAR) introduced invited participants to a new Irrigation Consortium, a proposed collaboration developed by the Colorado Water Institute, the Irrigation Association and FFAR. Presenters gave an overview of the consortium and discussed its potential role in supporting research on water availability, agricultural water use and efficiencies, and the need for better understanding of applied science surrounding irrigation. It concluded with an open forum for discussion.

**SPEAKERS:**

**LaKisha Odom,** Scientific Program Director, Foundation for Food and Agriculture Research; Washington, D.C.

**Stephen Smith,** Water Resources Engineer, representing the Colorado Water Institute and the Irrigation Association; Fort Collins, Colorado

#### DEVELOPING WATER STRESS TOLERANT CROPS THROUGH IMAGE-DRIVEN PLANT PHENOTYPING

This technical session emphasized advancements in the development of new genotypes with improved photosynthetic and water efficiency that can better adapt to climate variability through breeding and molecular transformation, and the role of sensing technologies, such as high throughput plant phenotyping, and leaf to field scale measurements in speeding up the selection process and development of new genotypes. Presenters highlighted the genotypes by environment and management interactions, with an emphasis on drought and other abiotic stresses.

**MODERATOR:**

**Archie Clutter,** Dean Agricultural Research Division, Institute of Agriculture and Natural Resources, University of Nebraska–Lincoln

**PANELISTS:**

**Yufeng Ge,** Daugherty Water for Food Global Institute Faculty Fellow; Assistant Professor, Biological Systems Engineering, University of Nebraska–Lincoln

**Pat Morgan,** Senior Scientist, LI-COR Biosciences; Lincoln, Nebraska

**James Schnable,** Daugherty Water for Food Global Institute Faculty Fellow; Assistant Professor, Department of Agronomy and Horticulture, University of Nebraska–Lincoln

**Addie Thompson,** Postdoctoral Research Associate, Department of Agronomy, Purdue University; West Lafayette, Indiana

**Harkamal Walia,** Daugherty Water for Food Global Institute Faculty Fellow; Associate Professor, Department of Agronomy and Horticulture, University of Nebraska–Lincoln

### KEEP IN COVERED: LESSONS FROM NEBRASKA'S COVER CROP EXPERIENCE AND GLOBAL APPLICATIONS

This session reviewed ongoing Nebraska cover crop research and extension efforts and potential applications to cropping systems in other countries. While cover crops have the potential to benefit ecosystems, they may also negatively affect crop yields and water balances. Speakers helped clarify where cover crops best fit in cropping systems, along with their potential and differing environmental roles. They also addressed water requirements when cover crops are added to a system.

**MODERATOR:**

**Roger W. Elmore,** Daugherty Water for Food Global Institute Faculty Fellow; Professor of Agronomy and Extension Cropping Systems Specialist, University of Nebraska–Lincoln

**SPEAKERS:**

**Burdette Barker,** Graduate Student, Biological Systems Engineering, University of Nebraska–Lincoln

**Humberto Blanco,** Associate Professor, Agronomy and Horticulture, University of Nebraska–Lincoln

**Cody Creech,** Assistant Professor, Agronomy and Horticulture, University of Nebraska–Lincoln

**Daren Redfearn,** Associate Professor, Agronomy and Horticulture, University of Nebraska–Lincoln

**Martha Shulski,** Nebraska State Climatologist; Director, Nebraska State Climate Office; Applied Climate Science Mission Area Leader; School of Natural Resources, University of Nebraska–Lincoln

## Luncheon Keynote Address

**Timothy Prewitt,** Chief Executive Officer, iDE; Denver, Colorado
*Global Impact: Poverty, Food Security and Solutions*

## Water and Society Student Showcase

Undergraduate and graduate students from the University of Nebraska–Lincoln, together with DWFI interns, shared their project work related to water, food and energy through multimedia displays and guided discussions.

### WATER FRONTIERS I: DROUGHT, WATER RISK AND THE CONTEXT FOR WATER MARKETS

This workshop, part one in a series funded by the U.S. Department of Agriculture and in partnership with the National Drought Mitigation Center, outlined common elements and decision-making in market-based approaches to improving water use for drought risk management. Presenters explored the water transaction outlook, water policy trends and the role of public versus private investment in facilitating water markets.

**MODERATOR:**

**Nick Brozović,** Director of Policy, Daugherty Water for Food Global Institute; Lincoln, Nebraska

**SPEAKERS:**

**Christopher Hartley,** Deputy Director and Senior Environmental Markets Analyst, Office of Environmental Markets, U.S. Department of Agriculture; Washington, D.C

**Richael Young,** President, Mammoth Trading; Denver, Colorado

## ETHIOPIA: LESSONS LEARNED IN WATER AND FOOD SECURITY

This session examined Ethiopia's humanitarian crisis in light of the significant international assistance it has received to address water and food insecurity: What lessons have been learned after decades of interventions across a wide variety of sectors, including agriculture, food security and water policy? What projects and interventions have been most successful and why? Given that more than 10 million people in Ethiopia have been affected by acute food insecurity conditions and below-average rainfall, exacerbating political tensions, what can international actors do to prevent violence and enhance food and water security? Panelists also drew attention to the challenges of incorporating local lessons and local voices.

**MODERATOR:**

**Roberto Lenton,** Professor, Biological Systems Engineering, University of Nebraska–Lincoln; Daugherty Water for Food Global Institute Distinguished Fellow

**SPEAKERS:**

**Peter G. McCornick,** Executive Director, Daugherty Water for Food Global Institute; Lincoln, Nebraska

**Patrice McMahon,** Daugherty Water for Food Global Institute Faculty Fellow; Associate Professor, Department of Political Science, University of Nebraska–Lincoln

**Tsegaye Tadesse,** Daugherty Water for Food Global Institute Faculty Fellow; Associate Professor, Climatologist and Remote Sensing Expert, National Drought Mitigation Center, University of Nebraska–Lincoln

**Nicole Wall,** Research and Outreach Specialist, National Drought Mitigation Center, University of Nebraska–Lincoln

**Timothy Williams,** Director for Africa, International Water Management Institute; Accra; Ghana

## WATER PRODUCTIVITY OF AGRICULTURAL SYSTEM

Panelists discussed the latest research and technical innovations in monitoring and measuring water productivity through remote sensing and data collection to evaluate water and agricultural productivity gaps.

**MODERATOR:**

**Christopher Neale,** Director of Research, Daugherty Water for Food Global Institute; Lincoln, Nebraska

**PANELISTS:**

**Ivo Zution Goncalves,** Postdoctoral Research Associate, Daugherty Water for Food Global Institute, Lincoln, Nebraska

**Patricio Grassini,** Daugherty Water for Food Global Institute Faculty Fellow; Cropping Systems Agronomist, University of Nebraska–Lincoln

**Mesfin Mergia Mekonnen,** Postdoctoral Research Associate, Daugherty Water for Food Global Institute, Lincoln, Nebraska

**Susanne Scheierling,** Senior Irrigation Water Economist, World Bank; Washington, D.C.

## WATER FRONTIERS II: CASE STUDIES OF WATER MARKETS 1

This workshop, part two in a series funded by the U.S. Department of Agriculture and in partnership with the National Drought Mitigation Center, outlined common elements and decision-making in market-based approaches to improving water use for drought risk management. Presenters examined the challenges and opportunities in establishing Australia's water markets and riparian water markets in Alabama, and considered other formal and informal water markets for drought risk management.

**MODERATOR:**

**Christopher Hartley,** Deputy Director and Senior Environmental Markets Analyst, Office of Environmental Markets, U.S. Department of Agriculture; Washington, D.C

**SPEAKERS:**

**Colin Chartres,** Director of Training and Master Classes, Crawford Fund, Australia; Adjunct Professor, Institute of Applied Ecology, University of Canberra, Australia

**John R. Christy,** Distinguished Professor of Atmospheric Science, Director of the Earth System Science Center, Alabama State Climatologist, University of Alabama in Huntsville

**John Tracy,** Texas Water Resources Institute, Texas A&M University; College Station, Texas

### FOOD, ENERGY AND WATER EDUCATION: RESEARCH, DEVELOPMENT, EXTENSION AND OUTREACH

In this structured poster session, presenters drew from a set of national food, energy and water (FEW) education projects to highlight resources, models and tools (RMTs) being used to cultivate science literacy within and across the FEW-Nexus. Participants explored diverse RMTs and learned how the different approaches can advance systemic efforts to support FEW education. The session aimed to leverage efforts associated with a newly established Multistate Research Committee – Collaborative for Research on Food Energy and Water Education (NCDC231) – and the Science Literacy Initiative in the UNL Institute of Agriculture and Natural Resources. Outcomes included distillation and identification of themes (e.g. challenges and contributions) in RMTs and next steps to develop RMTs that enhance current and future FEW education efforts.

**MODERATOR:**

**Cory Forbes,** Daugherty Water for Food Global Institute Faculty Fellow; Associate Professor of Science Education, Coordinator, Institute of Agriculture and Natural Resources Science Literacy Initiative, School of Natural Resources, University of Nebraska–Lincoln; Director, Nebraska Collaborative for Food, Energy and Water Education

**PANELISTS:**

**Leilani Arthurs,** Assistant Professor of Earth & Atmospheric Sciences, University of Nebraska–Lincoln

**Gillian Roehrig,** Professor and President, Association for Science Teacher Education, University of Minnesota

**Troy D. Sadler,** Professor and Director, ReSTEM Institute: Reimagining and Researching STEM Education, University of Missouri

**Jeyam Subbiah,** Kenneth E. Morrison Distinguished Professor of Food Engineering, Biological Systems Engineering and Food Science & Technology, University of Nebraska–Lincoln

## Opening Reception: An Evening at the Sheldon

Participants enjoyed an elegant reception at the Sheldon Museum of Art, including a globally inspired menu and acoustic music by Jarana, a duo blending South American, African and Mediterranean rhythms. Guests also viewed the multimedia exhibit, "Dreams to Dust: A Historical Example of a Midwestern American Natural Catastrophe and its Relevance Today," which shed light on our connection to the land over time through photography and cinematic film. The exhibit included the film, "The Idea of a Land Ethic: The Art of Human Connect to the Land" and a Q&A with teacher and artist Amanda Breitbach – the film's subject. The exhibit was created by DWFI Program Associate Morgan Spiehs and Undergraduate Intern Madeline Cass.

# TUESDAY, APRIL 11

## Plenary Session I

### Introduction and Overview: Water for Food Security: From Local Lessons to Global Impacts

**WELCOME**

**Hank M. Bounds,** President, University of Nebraska

**OPENING REMARKS**

**Peter G. McCornick,** Executive Director, Daugherty Water for Food Global Institute; Lincoln, Nebraska

**OVERVIEW**

**Jeff Raikes,** Co-founder, Raikes Foundation; Board Chair, Daugherty Water for Food Global Institute; Seattle, Washington

**AWARD PRESENTATION**

**DWFI Board of Directors and Leadership**

Outgoing Board Chair Jeff Raikes was recognized for his outstanding leadership and contributions to the institute and its global mission to help ensure water and food security with the "Water for Food Champion" award.

**SPEAKERS:**

**Alan Kolok,** Daugherty Water for Food Global Institute Faculty Fellow; Professor and Director, Nebraska Watershed Network, University of Nebraska at Omaha
*Developing the Worldwide Freshwater Water Quality Map*

**Steven Schonberger,** Practice Manager for Middle East and North Africa Region and Global Lead for Water in Agriculture, Water Global Practice, World Bank; Washington, D.C.
*Why the World Bank Cares about Water for Food and What We are Doing about It*

## Plenary Session II

**Sithembile Ndema Mwamakamba,** Climate Smart Agriculture Program Manager; Food, Agriculture and Natural Resources Policy Analysis Network; Johannesburg, South Africa
*Water and Irrigation Productivity in Small Scale Communal Irrigation Systems in Africa*

**Ann M. Bartuska,** Acting Under Secretary for Research, Education and Economics, U.S. Department of Agriculture; Washington, D.C.
*Agriculture in a Water-limited World*

## Luncheon Keynote Address

**Robert Bertram,** Chief Scientist, Bureau for Food Security, U.S. Agency for International Development; Washington, D.C.
*Role of Water in Food Security Investment Strategies under the Global Food Security Act*

## Concurrent Sessions

### UPSCALING SOLUTIONS: EXPANDING ACCESS TO IRRIGATION FOR SMALLHOLDERS IN SUB-SAHARAN AFRICA I

This session explored how public and private sector investors can support smallholder-irrigated agriculture in sub-Saharan Africa to sustainably and cost-effectively achieve greater yield gains and improve livelihoods. The session outcomes include a whitepaper synthesis of the case studies, panelist and participant input, which will serve as a basis for support to smallholder irrigated agriculture initiatives, further study and incorporation in major events such as Africa Water Week, 2017 World Water Week in Stockholm and the 2018 World Water Forum in Brasilia, Brazil.

**INTRODUCTION**

**Timothy Williams,** Director for Africa, International Water Management Institute; Accra; Ghana

**PANELISTS:**

**Ayembilla Joseph Anyagbilla,** Human Development Coordinator, Catholic Diocese of Navrongo-Bolgatanga; Ghana

**Richard D. Berkland,** Vice President of Market Development, Global Irrigation Division, Valmont Industries, Inc.; Omaha, Nebraska

**Martin Fisher,** Co-founder and Chief Executive Officer, KickStart International; San Francisco, California

**Meredith Giordano,** Principal Researcher and U.S. Representative for the International Water Management Institute; Washington, D.C.

**Ruth Meinzen-Dick,** Senior Research Fellow, International Food Policy Research Institute; Washington, D.C.

**Sithembile Ndema Mwamakamba,** Climate Smart Agriculture Program Manager; Food, Agriculture and Natural Resources Policy Analysis Network; Johannesburg, South Africa

**Timothy Prewitt,** Chief Executive Officer, iDE; Denver, Colorado

## WATER FRONTIERS III: CASE STUDIES OF WATER MARKETS, PART 2

This workshop, part three in a series funded by the U.S. Department of Agriculture and in partnership with the National Drought Mitigation Center, outlined common elements and decision-making in market-based approaches to improving water use for drought risk management. Presenters examined the role of transaction costs in water markets and other markets, and discussed a variety of water transactions for achieving environmental and other goals.

**MODERATOR:**

**Gregory W. Characklis,** Philip C. Singer Distinguished Professor, Director, Center for Watershed Science and Management, Institute for the Environment; University of North Carolina at Chapel Hill, North Carolina

**PANELISTS:**

**Kate Zook,** Program Analyst, Office of Environmental Markets, U.S. Department of Agriculture; Washington, D.C.

**Michael Brady,** Assistant Professor, School of Economic Sciences, Washington State University; Pullman, Washington

**Kristiana Hansen,** Assistant Professor, Department of Agricultural and Applied Economics, University of Wyoming; Laramie, Wyoming

**George Oamek,** Economist with Headwaters Corporation, serving as part of Executive Directors Office for Platte River Recovery Implementation Program

**Kent Miller,** General Manager, Twin Platte Natural Resources District, North Platte, Nebraska

**Mani Rouhi Rad,** Post-Doctoral Scholar, Yale School of Forestry and Environmental Studies; New Haven, Connecticut

## WATER GOVERNANCE AND MANAGEMENT IN GREAT RIVER BASINS I

This session was the first in a two-part series focused on the Great River Basins. Presenters discussed case studies and projects focusing on water quantity and quality in selected major river basins in the U.S. – the Colorado and Rio Grande Rivers and the Missouri River System – and the Ganges River in India, all with competing interests for freshwater and complex regulation and governance structures.

**MODERATOR:**

**Christopher Neale,** Director of Research, Daugherty Water for Food Global Institute; Lincoln, Nebraska

**PANELISTS:**

**Luna Bharati,** Principal Researcher-Hydrology and Water Resources, International Water Management Institute; Bonn, Germany

**Robert B. Jacobson,** Supervisory Research Hydrologist, River Studies Branch, Columbia Environmental Research Center, U.S. Geological Survey; Columbia, Missouri

**John (Jack) Schmidt,** Professor, Department of Watershed Sciences, Utah State University; Logan, Utah

## UPSCALING SOLUTIONS: EXPANDING ACCESS TO IRRIGATION FOR SMALLHOLDERS IN SUB-SAHARAN AFRICA II

This session included case studies and discussions on ways to develop next steps for expanding irrigation access to smallholder farmers in sub-Saharan Africa.

**MODERATOR:**

**Peter G. McCornick,** Executive Director, Daugherty Water for Food Global Institute; Lincoln, Nebraska

**INTRODUCTION:**

**Francois Onimus,** Senior Water Resources Specialist, World Bank; Washington, D.C.

**PANELISTS:**

**Mbogo Futakamba,** Ministry of Water and Irrigation; Tanzania

**Meredith Giordano,** Principal Researcher and U. S. Representative for the International Water Management Institute, Washington, D.C.

**Biniam Iyob,** Water and Irrigation Advisor, Bureau for Food Security, USAID; Washington, D.C.

**Ruth Meinzen-Dick,** Senior Research Fellow, International Food Policy Research Institute; Washington, D.C.

**Timothy Williams,** Director for Africa, International Water Management Institute; Accra; Ghana

## WATER FRONTIERS IV: FUTURE TOOLS AND DIRECTIONS

This workshop, part four in a series funded by the U.S. Department of Agriculture and in partnership with the National Drought Mitigation Center, outlined common elements and decision-making in market-based approaches to improving water use for drought risk management. Presenters examined the limits of water markets as a risk management tool, the legal outlook for water transactions, as well as the role of new tools and technologies in facilitating water transactions.

**MODERATOR:**

**Kate Zook,** Program Analyst, Office of Environmental Markets, U.S. Department of Agriculture; Washington, D.C.

**PANELISTS:**

**Gregory W. Characklis,** Philip C. Singer Distinguished Professor, Department of Environmental Sciences and Engineering; Director, Center for Watershed Science and Management, Institute for the Environment, University of North Carolina at Chapel Hill

**Harriett Hageman,** Managing Partner, Hageman Law; Cheyenne, Wyoming

**Christopher Hartley,** Deputy Director and Senior Environmental Markets Analyst, Office of Environmental Markets, U.S. Department of Agriculture; Washington, D.C

**Mike Joliffe,** Chief Water Officer, Upstream Tech; Syracuse, New York

**Mark Svoboda,** Daugherty Water for Food Global Institute Faculty Fellow; Director, Associate Research Professor, National Drought Mitigation Center, University of Nebraska–Lincoln

## WATER GOVERNANCE AND MANAGEMENT IN GREAT RIVER BASINS II

This session continued the earlier discussion focused on the Great River Basins, focusing on the question of whether agriculture must suffer the impacts from water releases in order to maintain in-stream flows.

**MODERATOR:**

**John (Jack) Schmidt,** Professor, Department of Watershed Sciences, Utah State University

**PANELISTS:**

**Jerry Kenny,** Executive Director, Platte River Recovery Implementation Program; Kearney, Nebraska

**Bradley H. Udall,** Senior Water and Climate Scientist and Scholar, Colorado Water Institute, Colorado State University; Fort Collins, Colorado

## GROWING THE WORLD'S LARGEST AGRICULTURAL PRODUCER DATABASE – WHAT'S THE YIELD?

Undergraduate students in the University of Nebraska-Lincoln's Raikes Design Studio have teamed up with faculty to develop an online database that will house the world's largest field-level producer dataset. The goal is to provide a useful, anonymized information source that producers, producer groups, researchers and water managers can use to make wise decisions to enhance agricultural productivity. The students provided a demonstration of the database and its functionality, and discussed their experiences learning from Nebraska producers on how to make data more useful.

**INTRODUCTION:**

**Jeff Raikes,** Co-founder, Raikes Foundation; Board Chair, Daugherty Water for Food Global Institute; Seattle, Washington

**MODERATOR:**

**Kate Gibson,** Program Coordinator, Daugherty Water for Food Global Institute, University of Nebraska; Lincoln, Nebraska

**PANELISTS:**

**Patricio Grassini,** Daugherty Water for Food Global Institute Faculty Fellow; Cropping Systems Agronomist, University of Nebraska–Lincoln

**Ashlyn Lee,** Undergraduate Student, Raikes School of Computer Science and Management, University of Nebraska–Lincoln

**Jeremy Suing,** Design Studio Project Manager, Raikes School of Computer Science and Management, University of Nebraska–Lincoln

**Fatima-Amor Tenorio,** Graduate Student, Agronomy, University of Nebraska–Lincoln

**Austin Wendt,** Undergraduate Student, Raikes School of Computer Science and Management, University of Nebraska–Lincoln

## Nebraska Bar-Be-Que at Roca Berry Farm

Participants traveled to Roca, Nebraska for a special Nebraska-themed reception and bar-be-que dinner with live music by the Boomtown Boys. The event featured Nebraska craft beer favorites and locally sourced beef brisket, chicken sliders and vegetarian delights. The beautiful, 100-year-old Creekside Barn at Roca Berry Farm was the perfect setting to celebrate our global conference and Nebraska's 150th year of statehood.

# WEDNESDAY, APRIL 12

## Plenary Session III

**WELCOME**

**Michael Boehm,** Harlan Vice Chancellor, Institute of Agriculture and Natural Resources, University of Nebraska–Lincoln; University of Nebraska Vice President for Agriculture and Natural Resources

**SPEAKERS**

**Brian Richter,** Director, Global Freshwater Strategies, Nature Conservancy; President, Sustainable Waters; Crozet, Virginia
*Chasing Water in a Dynamically Changing World*

**Chandra Madramootoo,** James McGill Professor, Bioresource Engineering Department, Faculty of Agriculture and Environmental Sciences, McGill University; Quebec, Canada
*Irrigation and Value Chain Development*

## Concurrent Sessions

### GROUNDWATER GOVERNANCE FROM FIELD TO GLOBAL SCALES

This session examined groundwater governance case studies from around the world, including the western U.S., India, South America and the Middle East and North Africa region. Presenters shared their experiences of how to make governance work, with a variety of perspectives from local to global scales. Cases included both high productivity and smallholder systems, with a range of management experiences.

**MODERATOR:**

**Nick Brozović,** Director of Policy, Daugherty Water for Food Global Institute; Lincoln, Nebraska

**PANELISTS:**

**Christina Babbitt,** Manager, California Groundwater Program, Environmental Defense Fund; San Francisco, California

**Mohamed Bazza,** Senior Water Resources Officer, Land and Water Division, Food and Agriculture Organization of the United Nations; Italy

**Jeff Fassett,** Director, Nebraska Department of Natural Resources; Lincoln, Nebraska

**Marcos Heil Costa,** Climate Scientist, Universidade Federal de Viçosa; Brazil

**Ruth Meinzen-Dick,** Senior Research Fellow, International Food Policy and Research Institute; Washington, D.C.

## CLIMATE CHANGE IMPACTS ON WATER AND AGRICULTURE: DEVELOPING COUNTRY-LEVEL STRATEGIES

Climate change in coming decades will have a significant impact on the quantity and quality of water resources available for agriculture – globally and locally. Understanding the projected changes in climate and dealing with these impacts and their consequences requires interdisciplinary collaboration. Scholars, technical personnel and policymakers involved in developing solutions to the impacts of climate change on water and agriculture shared their perspectives, touching on research, teaching and service components.

**MODERATOR:**

**Clinton Rowe,** Daugherty Water for Food Global Institute Faculty Fellow; Professor, Earth and Atmospheric Sciences, University of Nebraska–Lincoln

**PANELISTS:**

**Caspar Ammann,** Climate Science and Applications Division, National Center for Atmospheric Research; Boulder, Colorado

**Jayaka Campbell,** Research Fellow, Department of Physics, University of the West Indies; Kingston, Jamaica

**Alfred Grunwaldt,** Climate Change and Sustainable Development Sector, Interamerican Development Bank; Washington, D.C.

**Juan Jose Nieto,** Centro Internacional para la Investigación del Fenómeno de El Niño- CIIFEN; Quito, Ecuador

**Robert Oglesby,** Daugherty Water for Food Global Institute Faculty Fellow; Professor, Climate Modeling, University of Nebraska–Lincoln

**Tsegaye Tadesse,** Daugherty Water for Food Global Institute Faculty Fellow; Professor, School of Natural Resources, University of Nebraska–Lincoln

**Azar Abadi,** PhD Student, Department of Earth and Atmospheric Sciences, University of Nebraska–Lincoln

## EMPOWERING THE WATER COMMUNITY: CITIZEN SCIENCE IN ACTION

This session gave participants a close look at developing a citizen science program from start to finish. Presenters outlined the steps involved in completing a project focused on water quality monitoring of herbicides and nutrients across Nebraska. Presenters discussed the process of developing a web-based data management system and selecting analytical tools for reliable and precise water quality measurement. The session aimed to give participants a clear understanding of the power and pitfalls of citizen science and the importance of developing community ties.

**MODERATOR:**

**Alan Kolok,** Daugherty Water for Food Global Institute Faculty Fellow; Professor and Director, Nebraska Watershed Network, University of Nebraska at Omaha

**PANELISTS:**

**Shannon Bartelt-Hunt,** Daugherty Water for Food Global Institute Faculty Fellow; Associate Professor, Civil Engineering, University of Nebraska–Lincoln

**Ann Fruhling,** Professor and Director, School of Interdisciplinary Informatics, University of Nebraska at Omaha

**Krystal Herrmann,** Program Manager, Nebraska Watershed Network, University of Nebraska at Omaha

## HEALTH AS A HUMAN RIGHT

This session aimed to advance our understanding of rural communities in fostering citizens' perceptions of health as a human right. Presenters discussed the findings from a survey project conducted in Ainsworth, Nebraska that aimed to assess environmental factors contributing to well-being, such as clean water, nutrition and healthy livestock. Participants were asked to consider the importance of communities in improving life in rural America. Furthermore, this session helped deepen our understanding of how one research project can incorporate multiple actors, including rural youth.

**MODERATOR:**

**Peter Longo,** Daugherty Water for Food Global Institute Faculty Fellow; Professor, Political Science Department, University of Nebraska at Kearney

**PANELISTS:**

**Satoshi Machida,** Associate Professor, Political Science Department, University of Nebraska at Kearney

**Chuck Rowling,** Assistant Professor, Political Science Department, University of Nebraska at Kearney

## Luncheon and Award Presentations

**8TH WORLD WATER FORUM PRESENTATION**

**Dale Jacobson,** Governor, World Water Council; Omaha, Nebraska

**POSTER AND PHOTOGRAPHY COMPETITION AWARD PRESENTATIONS**

**Jesse Starita,** Education and Outreach Associate, Daugherty Water for Food Global Institute; Lincoln, Nebraska

**Amber Poythress,** Events Coordinator, Daugherty Water for Food Global Institute; Lincoln, Nebraska

## View From the Field

Farmers from Nebraska, California and Brazil shred their experiences and discussed water management practices in agriculture, touching on their common challenges and unique differences.

**MODERATOR:**

**Ron Yoder,** Associate Vice Chancellor, Biological Systems Engineering, University of Nebraska–Lincoln

**SPEAKERS:**

**Brant Burkey,** Owner, Burkey Farms Inc.; Director of Product, IntelliFarm, Inc.; Lincoln, Nebraska

**Leon Kriesel,** Owner, Kriesel Certified Seed; Gurley, Nebraska

**Danny Merkley,** California Farm Bureau; Sacramento, California

**Celestino Zanella,** Pivot Farmer and President of the Association of Farmers and Irrigators of Bahia (AIBA); Brazil

## Closing Panel

Panelists from a variety of disciplines gathered to review and reflect on the conference sessions, specifically addressing what they learned regarding local lessons translating into global impacts: major opportunities, challenges and next steps necessary to address the world's pressing water and food security needs.

**MODERATOR:**

**Roberto Lenton,** Professor, Biological Systems Engineering, University of Nebraska–Lincoln; Daugherty Water for Food Global Institute Distinguished Fellow

**PANELISTS:**

**Michael Boehm,** Harlan Vice Chancellor, Institute of Agriculture and Natural Resources, University of Nebraska–Lincoln; University of Nebraska Vice President for Agriculture and Natural Resources

**Margaret Catley-Carlson,** DWFI International Advisory Panel member; Vice Chair, Canadian Water Network, Vancouver, Canada

**Marcos Folegatti,** DWFI International Advisory Panel member; Professor of Biosystems Engineering, University of São Paulo, Brazil

**Giovanni Piccinni,** Global Production Sustainability Lead, Monsanto Co; St. Louis, Missouri

## Student Showcase and Art Show

On the last day of the conference, participants were invited to view a diverse selection of art and infographics by local professional artists and University of Nebraska–Lincoln students. Artists and students were available to discuss their work related to water, food and environmental sustainability.

## Closing Plenary and Heuermann Lecture

**Arthur Gen "A.G." Kawamura,** Founding Co-Chair, Solutions from the Land and former California Secretary of Agriculture; Irvine, California
*Whisky is for Drinking. Water is for Living…*

The challenges facing this century's thirsty and hungry world provide us with both threats and opportunities. Our past collective human experience can help us understand where we've been; however, our focus must lie on the new thinking and vision required to embrace the future. Society must not allow "deferred maintenance" or "deferred thinking" to delay the agricultural renaissance ahead. It is time to address the difficult work ahead through a collaborative and solution-oriented approach to our agricultural endeavors. Kawamura addressed how creating abundant water, food and energy systems forms the framework for a thriving world.

## Closing Reception: Celebrating Progress And Promise

Participants took part in a lively celebration of African culture and flavors – a nod to the progress and promise of improving water and food security in sub-Saharan Africa. The event featured African-inspired décor, food and refreshments, with a special interactive performance by the African Culture Connection.


*Graduate student Amanda Easterly (right), Department of Agronomy and Horticulture, University of Nebraska–Lincoln, shares her research.*

## Juried Poster Competition

The 2017 Water for Food Global Conference featured a juried poster competition for graduate students. A record 50 poster abstracts were submitted in six categories reflecting the major conference themes, and more than 40 students presented their work onsite. Faculty, partners and other professionals submitted an additional 10 posters.

### *Online Competition*

Prior to the conference, student had the opportunity to enter an online competition. All winners received cash prizes and free registration to the conference. University of Nebraska faculty served as jurors for the online competition.

*Online first place winner Naisargi Dave with the Nebraska Corn Board's Boone McAfee*

FIRST PLACE ($1,000): **Naisargi Dave,** Department of Biological Systems Engineering, University of Nebraska–Lincoln; "Quantifying Cost-Efficiency of Streambank Stabilization Practices on Cedar River, Nebraska"

SECOND PLACE ($750): **Mustapha Alhassan,** Department of Agricultural Economics, University of Nebraska–Lincoln; "Smallholder Irrigation Farmers' Preferences for Groundwater Protection under the Vea Irrigation Scheme in Ghana"

THIRD PLACE ($500): **Brandon Noble,** Department of Civil Engineering, University of Nebraska–Lincoln; "Experience Matters: Assessment Of Accuracy Of Water Quality Parameters Gathered By Various Classes of Citizen Scientists"

HONORABLE MENTION ($250): **Emmanuel Ahenkorah,** University of South Africa; "A Critical Investigation into the Effectiveness of Environmental Remediation Efforts in Steel Valley, South Africa"

### *On-site Competition*

All students who registered for the conference and entered the online competition were eligible to present their work at the on-site competition. The prize winners of the on-site competition were determined by a jury of 27 researchers and scientists at the conference. All winners received cash prizes and free registration to the conference.

*On-site first place winner CarlyRain Adams with the Nebraska Corn Board's Boone McAfee*

FIRST PLACE ($1,000): **CarlyRain Adams,** Food Science and Technology, University of Nebraska–Lincoln; "Energy-Water Reduction and Wastewater Reclamation in a Fluid Milk Processing Facility"

SECOND PLACE ($750): **Jonathan Ali,** University of Nebraska Medical Center; "Endocrine Challenges of A Midwest Upbringing: Investigating The Impacts Of Agricultural Runoff On Steroid Receptor Gene Expression, Growth And Development In Larval Fish"

THIRD PLACE ($500): **Sonja Loy,** Texas A&M University; "The Effect Of Greywater Irrigation On The Hydro-Structural Properties Of Two Kinds Of Soils"

*"Monsoon Fishing": First place winning photo by Sandipani Chattopadhyay*

## Photography Contest

DWFI received 33 entries from around the globe for its second annual photography competition, which was judged by a panel of professional photographers. The Viewers' Choice competition was determined by Facebook "likes." All of the photographs are available on our Facebook page under Photos.

FIRST PLACE ($100): **Sandipani Chattopadhyay**, Kolkata, India; "Monsoon Fishing"

FIRST RUNNER-UP ($75): **Debdatta Chakraborty**, Kolkata, India; "The Dal Lake Floating Market."

SECOND RUNNER-UP ($50): **Jayson Berto**, Science City of Muñoz, Philippines; "Gentle Splashes of Rice"

VIEWERS' CHOICE: **Jayson Berto**, Science City of Muñoz, Philippines; "Gentle Splashes of Rice"

*The Boomtown Boys perform at Roca Berry Farm's Creekside Barn during the Nebraska Bar-be-que Dinner*

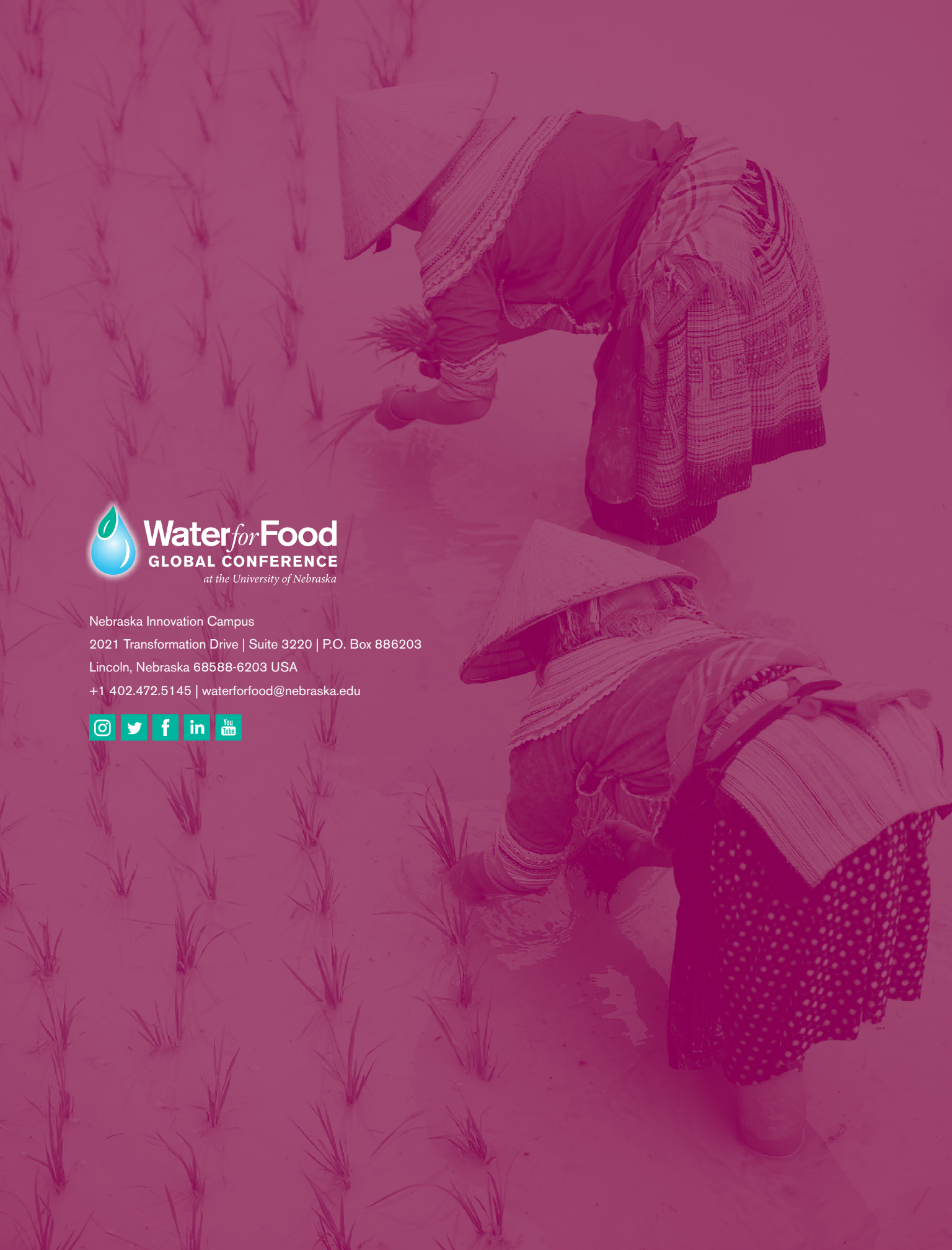
*Conference participants enjoy the opening reception at the Sheldon Museum of Art*

*From left: Nebraska PhD student Justin Gibson, DWFI Program Coordinator Kate Gibson and DWFI Faculty Fellow and University of Nebraska–Lincoln Assistant Professor Trenton Franz converse during a program break*

*Members of the African Culture Connection perform during the closing reception at the Nebraska Innovation Campus banquet hall*

*DWFI interns Alivia Michalski (left) and Shelby Wolfe present their professional development project to conference participants during a showcase exhibiting work by Nebraska students*

*KickStart International's Martin Fisher and Jenna Rogers-Rafferty chat with USAID's Biniam Iyob (center).*



Water for Food
GLOBAL CONFERENCE
at the University of Nebraska

Nebraska Innovation Campus
2021 Transformation Drive | Suite 3220 | P.O. Box 886203
Lincoln, Nebraska 68588-6203 USA
+1 402.472.5145 | waterforfood@nebraska.edu