Harnessing the Data Revolution

Ensuring Water and Food Security from Field to Global Scales

Proceedings of the 2014 Water for Food Global Conference
Seattle, Washington, USA | October 19–22

Water *for* Food
ROBERT B. DAUGHERTY INSTITUTE
at the University of Nebraska

Skyline of Bellevue, Washington (suburban Seattle).

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Bill & Melinda Gates Foundation Support

The sixth Water for Food Global Conference was held in a suburb of Seattle, Washington, in association with the Bill & Melinda Gates Foundation.

Thought Partners

The International Water Management Institute and the Global Water Initiative served as conference thought partners, taking an active role in developing the conference theme. IWMI and GWI offered strategic input on water and food issues specifically affecting smallholder farmers and connected DWFI with organizations that work closely with producers in this sector. Their global perspectives helped to frame the issues, identify speakers and attract engaged participants from around the globe.

The 2014 Water for Food Global Conference served as a North American Regional Event for the Seventh World Water Forum.

The issues discussed at the conference constituted an important dimension of the "Water for Food" theme of the Seventh World Water Forum held April 12-17, 2015 in Daegu and Gyeongbuk, South Korea. For this reason, the conference was designed to be part of the regional North American planning process for the forum, and was viewed as an opportunity to bring perspectives from stakeholders in the region and elsewhere as an important input to the event.

The Regional Process included several distinct global regions and the Americas Region included the sub-regions of North America, South America, Central America and the Caribbean. DWFI was the lead institution on water for food issues for both the Americas Regional Process and the North America sub-regional processes. The UN Food & Agriculture Organization led development of the water for food issue in the Thematic Process.

World Water Council

The World Water Council is an international multi-stakeholder platform. It was established in 1996 on the initiative of renowned water specialists and international organizations, in response to an increasing concern about world water issues from the global community.

The World Water Council's mission is to promote awareness, build political commitment and trigger action on critical water issues at all levels, including the highest decision-making level, and facilitate the efficient conservation, protection, development, planning, management and use of water in all its dimensions on an environmentally sustainable basis for the benefit of all life on Earth. By providing

a platform to encourage debates and exchanges of experience, the Council aims to reach a common strategic vision on water resources and water services management among all stakeholders in the water community. In the process, the Council also catalyzes initiatives and activities, whose results converge toward its flagship product, the World Water Forum.

worldwatercouncil.org

World Water Forum

Every three years, the World Water Forum mobilizes creativity, innovation, and know-how around water. Serving as a stepping-stone toward global collaboration on water challenges, the forum is a unique, multi-stakeholder platform where the water community and the policy and decision-makers from all regions of the world can work together to find joint solutions. It is the largest international event that seeks to advance the cause of water.

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Foreword

The explosion in data in recent years is influencing virtually every field of human endeavor. New and complex data sets —from cellphone communications to remote sensing — combined with greatly enhanced data processing capabilities are opening up new possibilities for better data-driven analysis and decision-making.

If effectively harnessed, data can transform farming from a labor-intensive, high-risk endeavor to a knowledge-based, strategic enterprise that manages risk and improves production for both large-scale and smallholder farmers. In high-tech contexts, for example, data generated by computer-aided tractors, irrigation equipment and other machinery can increase productivity through precision agriculture. These data-driven techniques enable farmers to reduce inputs, including water use, thereby helping agricultural systems become more efficient and sustainable. Furthermore, the availability of large volumes of data from multiple sources greatly enhances analysis and learning, revealing critical relationships that could vastly improve our understanding of agricultural water management and other critical determinants of water and food security.

At the suggestion of the Bill & Melinda Gates Foundation, the Robert B. Daugherty Water for Food Institute at the University of Nebraska (DWFI) hosted its sixth annual Water for Food Global Conference in Seattle, Washington. Drawing more than 250 practitioners, scholars, farmers and thought leaders from 23 countries, the conference delved into the many promises and challenges of data management in water management and food production contexts.

The conference topics enabled the sharing of multiple perspectives on data issues — exploring how funding organizations use data to select and evaluate programs, as well as how these efforts are helping to catalyze the adoption of technology and the benefits of the data revolution in low income countries; how the private sector uses data to guide research and development decisions and measure the successes of their products; and, how local data collection can be enhanced to benefit smallholder farmers.

Since 2010, the Water for Food Institute has furthered research, education and policy analysis to help ensure a water and food secure future. The institute extends the University of Nebraska's expertise through strong partnerships with other universities and public and private sector organizations. DWFI works locally and internationally, bridging the water and agricultural communities, as well as the world's smallholder and large-scale farmers, to deliver innovative solutions to this complex global challenge.

The conference is an excellent example of the institute's educational outreach and knowledge sharing through partnerships. We hope this report will help you better understand water and food security as a vital issue and how data can be an important tool in our efforts to meet the demands of a growing world population.

Jeff Raikes
Co-Founder, Raikes Foundation and Chair, DWFI Board of Directors

James Linder, M.D.
Interim President, University of Nebraska

Preface

I am pleased to introduce the proceedings of the sixth global Water for Food Conference, "Harnessing the Data Revolution: Ensuring Water and Food Security from Field to Global Scales." In association with the Bill & Melinda Gates Foundation, we brought the 2014 conference to Seattle, which provided an ideal setting for our focus on data technology and the potential it holds to transform agricultural water management for large and smallholder farmers around the world.

The 2014 conference focused on ways to effectively manage and use data-gathering technology to conserve water and improve agricultural production for farming systems at local and global scales. For this sixth annual conference — the first in a venue outside of Nebraska — a priority was to focus more sharply on the water and food issues affecting smallholder farmers and to increase the participation of people and organizations who work most closely on smallholder questions. To help us frame issues, identify speakers and increase the number of participants from this sector, we were pleased to work closely with two exceptional thought partners, the International Water Management Institute and the Global Water Initiative, who helped us ensure that the conference provided diverse perspectives and stimulated an active exchange of ideas. Presentations and panel discussions covered a range of topics, including the data needs of smallholder farmers, using climate data to improve decision-making, water's effect on public health, as well as the policy and economic implications of water metering.

The conference also introduced the Global Yield Gap and Water Productivity Atlas, a far-reaching project led by DWFI Faculty Fellows at the University of Nebraska–Lincoln and their colleagues at Wageningen University in the Netherlands that was initiated through a seed grant from DWFI. The atlas is a map-based web platform that helps identify where significant gaps exist between actual and potential yields, providing data to enable practical solutions on the ground.

As you'll discover in this report, the conference provided a forum to discuss major aspects of the data revolution, including the opportunities and the challenges it presents to large and smallholder farmers alike. Several speakers highlighted the difficulty of deriving useful information for policy and practice from the vast data available and how these difficulties can be overcome. A panel focused on smallholder farmers discussed how encouraging farmers to use data to improve their operations requires significant training and other agricultural outreach, which is difficult in countries where these services are limited. These discussions exemplify how the Water for Food Institute stimulates global policy debates that advance our understanding of new technologies and practices and their effective use, offering real solutions to ensure global water and food security.

I would like to express my appreciation to all our staff, collaborators and thought partners for their tremendous efforts in planning and executing the conference, and especially to my colleague Rachael Herpel, who played the lead role in the conference organization. I would also like to thank the Robert B. Daugherty Charitable Foundation, the Gates Foundation and our corporate sponsors for their generous financial support of the conference.

Roberto Lenton
Founding Executive Director
Robert B. Daugherty Water for Food Institute
at the University of Nebraska

Part One

Introduction

Data has the power to revolutionize our world — or so we often hear.

That's not hyperbole, said Jeff Raikes, of the Raikes Foundation. The data gathering capabilities of the digital and web-based era, combined with the computational power to deal with it all, is fundamentally changing everything from advertising to medicine. But the data revolution has yet to remake agriculture, he said.

The world's population is expected to reach 9.5 billion by 2050. Food production must double to meet rising demand, while using fewer water resources. The data boom offers a tremendous opportunity to help achieve that goal. When it comes to something as critical to the future of humanity as our shared and shrinking water resources, we can't afford to leave any solution behind, Raikes said.

But harnessing the data revolution also brings risks, challenges and conflicts that must be overcome. "We have to realize that these discussions we're having here are not just about data, they're not just about modeling," said Frank Rijsberman, of the CGIAR Consortium. "They grab people, they stir emotions and they are indeed right at the heart of the social debate."

Big Data

"Big data," characterized by extremely large and new sources of datasets, are an agricultural and water management "game changer," presenters agreed. Its utility stems from the patterns, trends and insights gleaned from analyzing such large and diverse volumes of data, and then using those insights to make better decisions that lead to greater water and food security.

Traditional methods of data analysis often struggle to handle big data, but the technology is catching up. The conference highlighted numerous tools and methods

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

Jeff Raikes

developed to analyze big — and little — data, whether collected from outer space or a farmer's field. The tools are helping to better understand current agricultural, water and natural systems; make predictions; and drive better management and policies.

High-tech farmers generate much data on their farms. Companies are developing cloud-based tools to help them use the

Neil Palmer, CIAT

data and incorporate weather and other information to make decisions, such as when and how much to irrigate, as well as whether to automate irrigation and other farm tasks. The private sector is also taking advantage of new data tools to more quickly create drought-resistant seed varieties and variable rate irrigation systems, among other advancements.

At the other end of the spectrum, some big data tools have the potential to "leapfrog" existing technologies in data-poor regions, particularly to aid smallholder farmers, much as cellphones negate the need for landlines in many poor countries. Remote sensing and digital soil mapping

is becoming less expensive and could, for example, surpass costly land-based data gathering techniques.

Other tools merge big data with local knowledge to help fill gaps in low resource settings, such as the University of Nebraska–Lincoln (UNL) and Wageningen University's Global Yield Gap and Water Productivity Atlas, which estimates gaps in crop yield and water productivity, and Mapeo Amano, which puts satellite images in the hands of El Salvadoran farmers to help drive locally generated solutions.

Citizen scientists are helping to fill in when governments fail to collect agriculturally relevant data. In one

example, the Community Collaborative Rain, Hail and Snow Network, or CoCoRHaS, mobilizes 20,000 volunteers to collect daily precipitation measurements throughout the U.S. This crowdsourcing of data is just one way in which people contribute. Social media, the Internet, cellphones and other technologies are used to conduct surveys in remote areas, quickly fill in maps during emergencies and identify disease trends, for example.

Risks and Challenges

Even as new data and data tools create opportunities to achieve water and food security, presenters described numerous risks and challenges posed by collecting and storing large amounts of data.

Farmers' fears regarding data privacy and security lead to distrust among farmers about how their data will be used and, thus, lower adoption of new technologies. The conference explored issues around data ownership, transparency and data sharing, the rights of farmers, and the responsibilities of private and public sectors entrusted with managing and protecting data.

Data reliability is another concern, and several speakers discussed the importance of "ground truthing," or verifying, remotely gathered data, as well as the importance of using local knowledge, particularly when researchers or program managers come from other cultures.

Although the use of big data provides exciting new opportunities for smallholders, a growing "digital divide" also threatens poor countries. As global agriculture increasingly relies on data and analytical capabilities, smallholder farmers and governments in resource-poor settings may be the least able to exploit data for their benefit. "We know more about the lives of small farmers than we've ever known before," Raikes said. "So let's use that information to work on solutions that are specifically designed for the billion smallholder farmers who desperately

Neil Palmer, CIAT

need solutions. If we harness the data revolution in the right way, we will be able to meet our most important goals."

Perhaps the biggest challenge to harnessing the data revolution for global agriculture, however, is adjusting political, social and economic structures to take advantage of the insights and opportunities that stem from it. Big data can create dazzling images, but how do you understand what

> "If we harness the data revolution in the right way, we will be able to meet our most important goals."
>
> — *Jeff Raikes*

is happening and why, and then collectively find and implement solutions? asked Jeremy Bird, of the International Water Management Institute.

Several panels highlighted the role institutions play in influencing how data is used — or misused — in water management and food production. Policy and governance, in particular, contribute significantly to agricultural decision-making in both large and smallholder settings. This role was highlighted in discussions regarding aquifer overpumping. In India, for example, policy incentives have led to the rapid exploitation and depletion of groundwater resources, Bird said. However, panelists also described how water metering, often a controversial and unpopular policy, can improve water productivity, extend the lifetime of aquifers and transform irrigated agriculture.

Equal effort must be put into the social dimension of agricultural systems, said Jennie Barron, of the Stockholm Environment Institute. Women, for example, play an enormous role in global agriculture and food security, but how gender affects a system's agricultural production or water use is often unavailable or not considered.

A major key to overcoming many of these challenges is to include farmers, policymakers, community members and others in creating and using the data, Raikes and others said. Solutions can then be tailored to meet their needs, and the process will create trust and reliability in the data.

New Realities, New Strategies

"We are entering a new world, a peak water world, in which there are actual limits to the amount of water we can take out of our systems," said Peter Gleick, of the Pacific Institute. Many of the world's regions have reached the full potential of their water supply, and we must focus on reducing demand, improving water use efficiency and protecting water resources. Traditional approaches to water will no longer suffice, he said.

UNL's Ken Cassman detailed five long-term trends causing disruptive changes to traditional ways of thinking: slowing rates of growth in yield, rising carbon dioxide emissions contributing to climate change, increasing food prices, increasing supplies of natural gas, and energy prices rising more quickly than agricultural commodity prices. "I don't think that, as an integrated group, we've brought them together to consider what it means for food security, for water security," Cassman said, during the Trends in Water and Agriculture Session.

Policy analyst Uma Lele added during the Closing Panel that as a consequence of declining food prices over the past century, south Asian and Sub-Saharan African governments, as well as foreign donors, have grown complacent and reduced agricultural investments. Now governments can't meet their countries' needs. Much more must be done with fewer resources, putting more pressure on partnerships and sharing knowledge, she said.

"Are we on course?" asked Cassman. "No, but we can get back on track." We must incorporate these trends into strategic planning to avoid misappropriating funds, he said.

Conclusion

There's no going back, said Victor Sadras, of the South Australian Research and Development Institute. Technology only moves forward. But while technology may solve problems, it often creates new ones requiring additional technology to solve.

A technology's trajectory and the socioeconomic and political factors that led to it are traceable. However, future technologies can't be predicted because of preadaptations, he said, during the Trends in Water and Agriculture Session. For example, Google wasn't designed to manage water, but the company is helping E. & J. Gallo Winery of California use high-resolution satellite images to manage irrigation because it's preadapted to work with the data.

So while we can't predict the discovery of the unknown, we also can't afford expensive disruptions, Sadras said, adding that the idea that we must work across disciplines is almost a cliché. "I think we need to be more assertive, and what I think we need to do is set as a condition that the problems are addressed by people who understand the problem at the right level of organization."

Neil Palmer, CIAT

Part Two

Technical Tools

CHAPTER 1: Understanding Climate

"Climate change has a taste; it tastes like salt," said Kristi Ebi, of the University of Washington, during the Impact of Water on Health Panel. Ebi was relaying the words of a Bangladeshi rice farmer struggling with saltwater intrusion. Current policies and programs assume a stationary climate, and that's no longer the case, she said. We won't solve climate change, so we must learn to manage it. How do we need to think differently?

To help answer that question, scientists are collecting data on the environmental and social impacts of climate change on a larger scale than ever before. The data is so voluminous, complex and disparate, however, that it's often difficult to analyze and interpret.

The explosion in climate data comes largely from sensor networks, both in space and on Earth, that continually record detailed information about weather, particulates, land use changes, water movement, oceans, and crop vitality, among other parameters. The increasing breadth and scope of data improve climate models, provide a deeper understanding of climate change and better project future climate, said Philip Mote, of the Oregon Climate Change Research Institute at Oregon State University, during the Data to Better Understand Climate Systems Panel. He described how climate models function and what they can — and can't — tell us about the future. Scientists divide the planet into a three-dimensional grid, within which atmospheric data is collected and the interactions between grids evaluated. Many global climate models exist, and they vary in quality and predictions, Mote cautioned. To get a more accurate climate picture, it's important to use a range of models. In addition to planetary level data, understanding the socioeconomic factors affecting greenhouse gas concentrations, such as fossil fuel emissions, is important because they're major climate change drivers, he said.

Kristi Ebi

The U.S. Drought Monitor, a map of drought and its impacts, has also benefited tremendously from the data revolution, said fellow panelist Mark Svoboda, of UNL. Published weekly through UNL's National Drought Mitigation Center in collaboration with the U.S. Department of Agriculture and the National Oceanic and Atmospheric Administration, the monitor has evolved from a few indices manually analyzed and drawn in the late 1990s to today's sophisticated assessment of current conditions at increasingly localized levels. The monitor's authors now analyze more than 5,000 data points, from stream flow to precipitation patterns, distill it and package it into a visually accessible format. Importantly, the map also includes drought impact, a ranking that incorporates objective historical data and context.

Numerous entities consult the monitor, Svoboda said, including national and state governments, which use it for fast-tracking disaster designations and long-term policy planning.

He also described a new tool available through the center. The Drought Risk Atlas brings precise climatological data to spatial scales that allow decision-makers to better understand drought in their region. Historical and current climatological data and gridded maps are available for the entire U.S.

"Tractors today have more computer power than the first spaceship that went to the moon," said Robert Fraley, executive vice president and chief technology officer at Monsanto Co. When effectively harnessed, tractor-generated yield information, GPS, soil moisture sensors, satellite data, weather information and other data-gathering tools allow farmers to precisely apply water, fertilizer and other inputs meter by meter within a field.

This precision agriculture, increasingly practiced in high-income farming regions, translates into higher yields using less water and energy and with less runoff and pollution. It can transform farming from a labor-intensive, high-risk endeavor to a knowledge-based business that manages risk and improves food production. Aggregated farm data also contributes to large-scale analyses, revealing critical relationships that can improve agricultural water management.

But first farmers must make sense of the data. Martin Pasman, a farmer and president of Valmont Industries de Argentina, expressed the frustration of many farmers during the Closing Panel, saying he gathers a lot of information on his farm, but lacks the tools or knowledge to use it.

In 2000, farms globally averaged just two data points daily to make decisions. By 2035, farmers will have nearly 4 million data points coming at them each day, said Lance Donny, of OnFarm Systems. "If we don't have systems that figure out how to deal with this data, how are we expecting them to use that information?"

Apps for That

A key focus in precision agriculture is knowing when and how much to irrigate. Already a large part of the food security solution, irrigation supports 40 percent of total food production, said Lee Addams, of Valmont Industries, during the Industry Leaders Session. The question is how to irrigate even more effectively. While precision agriculture provides more "crop per drop," another key consideration is "profit per drop," he said.

High-impact solutions are those that improve farmers' profits, achieved through

Center pivot irrigation.

From left: Terry Schiltz, James Krogmeier, Mark Reiman and Lance Donny.

increased production, decreased costs and limiting risks, Addams explained. These solutions include variable speed and rate irrigation based on soil and elevation data that translate into precise irrigation rate prescriptions. The data can then be analyzed to further improve yield practices. But convincing farmers that variable rate irrigation increases production and therefore profits can be challenging. Reducing energy costs by pumping less has a more immediate impact on the bottom line.

Many would agree that farmers don't want to waste water. But few systems are available to help analyze all of the variables to accurately determine when to irrigate. According to a 2008 USDA survey, most irrigation decisions are based on how the soil feels, he said. Fewer than 10 percent of farmers use technology, such as sensors or computers.

That leaves a lot of room for improvement, said Mark Reiman, of Monsanto's Gothenburg

Learning Center, a 320-acre irrigated and dry land demonstration farm in south-central Nebraska developed to help farmers increase yields using less water and other inputs.

His fellow panelists in the Innovations in Irrigation Data Systems Panel described tools that public and private entities are developing to help farmers corral and use their data. The companies OnFarm Systems and AgSense have each developed systems to gather farm and weather data from a variety of sources and then relay it to a cloud-based server for analysis. Cloud-based systems can be accessed through a variety of telecommunication systems, including radio, satellite and cellular, providing opportunities for use in developing countries as well.

Schiltz, of AgSense, described his company's farm management tool, WagNet, which allows farmers to access their farms' irrigation systems, soil conditions and weather data, remotely monitor and control irrigation, and forward information to an

agricultural advisor. WagNet increases water use efficiency, stores data records and, ultimately, provides near real-time information, Schiltz said, adding that simplifying the technology improves adoption of efficiency improvements.

OnFarm's service also collects local farm and weather data and uses analytic and communication tools through collaborations with other companies to help turn the data into knowledge farmers can use to optimize irrigation use, Donny said.

Cloud-based systems raise concerns that must be addressed, added James Krogmeier, of Purdue University. Specifically, farmers don't own their own data, systems can't work together and the current approach stifles innovation.

He described the Open Ag Data Alliance (OADA), a community of volunteers advocating for greater openness. Under the principle that farmers should own their own data, OADA is creating a set of freely available software tools and protocols to build applications that program developers can use to ensure data security and sharing across software platforms. This interoperability allows farmers the freedom to choose cloud providers while maintaining control over how their data is used. The ability to transfer services is key to allowing market forces to function properly and to encourage innovation, he said.

The OADA community is also developing guidelines outlining data privacy and use standards for future OADA certification. They expect OADA-supported commercial platforms to be available in 2015.

High-tech Smallholders?

While precision agricultural tools primarily focus on large farms in developed countries, several participants speculated on the appropriateness of high-tech solutions for smallholder farmers.

"One mistake that people sometimes make is assuming that if something's high-tech, then it can't work in poor countries to help poor farmers," Raikes said. "I despise that way of thinking."

To some extent, high-tech agriculture is already happening on some smallholder farms in low-income countries. Presenters described land leveling to increase water productivity in Pakistan, drones flying in Sri Lanka and new African drought-resistant seed varieties.

Though private sector discussions focused on products for largeholder farmers in high-income countries, representatives from irrigation, biotech and precision agriculture industries agreed that some web-based solutions and other successful technologies can be modified to fit smallholder settings as well. Bringing existing irrigation technology to smallholder farmers is challenged, however, by limited access to markets and small plot sizes, Addams said. The desire for mechanized irrigation — and its yield gains — exist in Africa, and incremental gains in irrigation access have been accomplished, but achieving scale is difficult.

Paul Hicks, who works on Central American agricultural issues for Catholic

"The lower hanging fruit for food security and for the farmers … is in the rainfed agriculture sector."

— *Paul Hicks*

Relief Services, reminded attendees during the View from the Field Panel that despite the importance of irrigation to global food production, rainfed agriculture still accounts for 80 percent of cropland and 60 percent of production. "The lower hanging fruit for food security and for the farmers . . . is in the rainfed agriculture sector," he said, adding that we must think about how to harness data and use tools focused on smallholder farmers that address food security and natural resource management issues.

Groundwater Measuring

Globally, agriculture consumes 70 percent of all freshwater withdrawals, much of it groundwater used for irrigation. In the past century, overpumping groundwater has seriously depleted aquifers in many areas worldwide, threatening those regions' agricultural future and economic vitality as well as food security globally. Lack of information regarding aquifer conditions and withdrawals have made it difficult to properly manager aquifers.

Recently, a data tool has succeeded in drawing attention to the plight of the world's aquifers. The Gravity Recovery and Climate Experiment (GRACE), launched in 2002 by NASA and the German Research Institute for Aviation and Space Flight, has provided dramatic images of just how depleted some aquifers have become.

Better managing groundwater use and preventing unsustainable aquifer depletion require knowing how much water is withdrawn. Yet it's often hard to know exactly how much and when water is being used for irrigation at a field level. Presenters in the Implications of Metering for Agricultural Water Management Panel discussed the pros and cons of implementing water meters to measure water use. Metering water can help farmers by reducing overwatering, increasing water use efficiency and lowering pumping costs

Slim Zekri

for groundwater-fed irrigation. Despite the benefits, water meters are often unpopular in both large and smallholder settings due, in part, to their potential use in enforcing water quotas.

Advances in equipment and wireless reporting, together with local governance and careful engagement activities, are overcoming some of these challenges. Oman, for example, initially rejected traditional groundwater flow meters because of high manual data retrieval and maintenance costs, said Slim Zekri, of Oman's Sultan Qaboos University. The country is experimenting with electronic smart water meters, which wirelessly send water use data daily. The data will help scientists determine sustainable aquifer withdrawals, establish quotas and better understand how much water crops require to improve yields.

In China, mechanical meters were prone to failure and tampering, so the country is converting to electronic smart metering systems in some areas, said Wolfgang Kinzelbach, of ETH Zürich. Farmers insert

Wolfgang Kinzelbach

a prepaid smart card to operate a well, and quotas can be enforced by placing limits on the card. Data from the metering systems is automatically transferred to a central agency via text messaging for analysis.

Evapotranspiration Data

Methods of measuring precipitation are relatively easy, at least compared to those for measuring the water that returns to the atmosphere. Globally, nearly 70 percent of water returns through evapotranspiration, or ET, the combination of evaporation from land surfaces and transpiration from plants. Therefore, measuring ET is important to understanding crop vitality and improving water management, including knowing when to irrigate, said Dave Johnson, of LI-COR Biosciences, during the Data from Field to Global Scales Panel. But many techniques measure potential, not actual, ET, which can lead to errors because it excludes important factors, such as soil moisture, climate and crop types.

The eddy covariance method measures actual ET by calculating changes in

water vapor measured in wind eddies on instruments affixed to towers. The method has evolved over recent years, generating tremendous amounts of data, Johnson said. He described LI-COR's user-friendly software products that process the data, including FLUXNET, which processes large amounts of data generated from a network of covariance stations. LI-COR is working with Chinese scientists to develop an eddy covariance network system to help them better understand agricultural water usage as they seek to increase food production.

Working at a larger scale, fellow panelist Martha Anderson, of the USDA's-Agricultural Research Service, and her colleagues use satellite remote sensing data to create ET maps. The maps quantify crop water productivity over landscapes, allowing researchers to study changes in water use patterns over time in response to changing climate and land uses, for example. ET maps can also help predict droughts and floods, improve short-term weather forecasts and aid in monitoring crop stress and yield estimations.

They are developing applications, both within the U.S. and in collaborations with other nations. For example, ET maps are helping Brazilian scientists better understand water use within competing systems, investigators in the Arabian Peninsula study the impacts of expanding irrigation water supplies, and insurance companies integrate remote sensing data into insurance programs for smallholder farmers in Sub-Saharan Africa.

Harnessing Floods

Floodwaters have been irrigating crops since the early Egyptians used the Nile to irrigate fields before planting. The annual floods were unpredictable, and those early water managers recognized the need for data. They created the Nilometer, a water gauge that measured the rising Nile to better predict when floods — and droughts — would occur.

Jeremy Bird

Today, satellites and computers have replaced the Nilometer. The International Water Management Institute uses remote sensing data and computer modeling to analyze flood patterns in Egypt and other African and Asian countries to accurately predict flood risk and to help farmers capture floodwaters for irrigation, said IWMI's Jeremy Bird. Working with governments, disaster management centers and private insurers, IWMI is also developing tools to help decision-makers better manage flood risk and adequately insure farmers against extreme weather events.

The goal is to empower smallholder farmers, the community and public institutions, said IWMI's Giriraj Amarnath. During the View from a Field Panel, he detailed two projects IWMI is developing to harness floodwater. The first, in Sudan, Ethiopia and Egypt, uses field specific crop, flood and weather data to create near real-time information on crop health and irrigation requirements at the farm level. Information farmers need to make decisions, such as how much water their fields received and for how many days, is available via the web and is sent via text

messaging to cellphones. IWMI provides phones and conducts field visits.

The second project assists the Nigerian government in harnessing floodwaters to increase smallholder agricultural production in river floodplains and to reduce risks. The project uses satellite imagery to determine the extent of flooding and the amount of cultivated agricultural land inundated by floodwater. When floods recede, the government quickly implements a crop information system to alert farmers to information they need to take advantage of floodwater.

Farming in the Desert

With drought likely to intensify in the Arabian Peninsula in coming years, the region will become even more reliant on world markets, said Pasquale Steduto, of the UN's Food and Agriculture Organization, during the Trends in Water and Agriculture Session. With almost zero food self-sufficiency, these desert countries use oil revenue to purchase food. The food crisis of 2008 was a "wake-up call" that even wealthy countries may be unable to access food, he said.

Steduto described a new generation of hydroponic greenhouses to provide food production with little water. The greenhouses are a closed system that eliminate the non-consumptive use of water and reduce evaporation and ET, the consumptive uses of water, by 30 percent. The consumed water is recaptured, condensed and reused, using methods that don't require energy.

The greenhouses provide wealthy, food-importing countries with marginal land an opportunity to provide more food internally, Steduto said. A wide variety of crops, trees and even animal feed can be grown in greenhouses. "The benefit in the use of these new generation greenhouses, after all, is they are the ultimate sustainable agriculture intensification solution," he said. FAO is working with partners to install prototypes in the United Arab Emirates and to assess the potential to scale the greenhouses throughout the Arab region.

Chapter 3: Genomics

Breakthroughs in sequencing entire plant genomes in the past decade have dramatically transformed agricultural research and crop breeding programs in developed countries.

Armed with entire genomic sequences and advanced computing power, scientists are able to more quickly create new genetic combinations. Computer algorithms link sequence data to crop performance in the field to predict which cultivars will perform well under drought or other adverse conditions while using fewer chemical pesticides. This biotechnology pipeline is underpinned by investments in data science, computer power

Robert Fraley

and advances in robotics that allow for tremendous precision, speed and reduced costs, said Monsanto's Robert Fraley.

"We absolutely have the opportunity to double production yields across the U.S. and Americas," he said. "As exciting to me is the ability to use these tools globally to drive a tripling and quadrupling of yields outside of the Americas as we look to the future."

Fraley's optimism is grounded in the increasing yields experienced since biotech crops were introduced in the mid-1990s. He compared the U.S. droughts of 1988 and 2012: Though 2012's drought was much more severe, yields were nearly 40 bushels per acre (2.5 tons/hectare) higher.

Despite big gains in developed countries, genomics and biotechnology are only now beginning to improve breeding programs in Africa and Asia, said Raikes. Commercial genome sequencing costs have dropped significantly, to less than $1 per plant, but are still 20 times higher for African and Asian crops. "We must make genotyping costs more equal," he said, adding that the Bill & Melinda Gates Foundation is investing in reducing genotyping costs for public breeding programs that serve smallholder farmers.

One effort to develop improved maize varieties for Sub-Saharan farmers is beginning to see success, Fraley said. The Water Efficient Maize for Africa (WEMA) project, a public-private partnership supported in part by the Gates Foundation, is using breeding and biotechnology to create drought- and pest-resistant maize hybrids. The new seed varieties will be made available to smallholder farmers in Sub-Saharan Africa royalty-free through African seed companies. Field tests of new varieties in Kenya yielded 71.7 bushels/acre (4.5 tons/ hectare), more than double normal average yields, Fraley said.

Chapter 4: Data Gaps

The conference also addressed the significant data gaps in poor countries, where data is hardest to obtain, but needed most. Even in wealthy countries, investment in publicly available soil and weather data is declining, leaving knowledge gaps in critical agricultural areas.

Tools are being developed to "leapfrog" existing technologies. Presenters described, for example, the benefits of cellphones, particularly in areas without landlines. Cellphones can be used to gather data, providing behavioral information to better target support, and to disseminate information, reaching subsistence farmers isolated by insufficient phone service and roads. Farmers can obtain weather forecasts and market information through their phones, as well as connect with other farmers.

Technology is only one aspect to filling gaps, several presenters said. Much data also resides with, or can be obtained by, the local community. Interpreting data really means understanding the landscape, said audience member Deborah Barry, of the Global Water Initiative. That invaluable knowledge and the ability to interpret data comes from local scientists, farmers and other community members. "Putting the two together is really important," she said.

Phillip Owens

Soil Mapping

Africa has the most depleted soils in the world and lacks updated soil maps, resulting in ineffective and costly agricultural practices, such as inefficient water use and subsidizing inappropriate fertilizers, said Raikes. To provide accurate soil information, the African Soil Information Service, or AfSIS, a global collaboration of research institutes and African governments funded by the Gates Foundation, is developing detailed digital soil maps for Sub-Saharan Africa using

historical records and new data tools, such as satellite remote sensing imaging, soil spectra lab analyses and crowdsourced ground observations.

Phillip Owens, of Purdue University, said during the View from the Field Panel that good soil maps are important to meet a wide variety of basic infrastructure needs in developing countries, such as flood and landslide predictions, erosion and aquifer recharge potential, biodiversity and building or road construction. Historically,

> "We have to have information at the level where people are making decisions, or we'll have very little impact on a larger scale."
>
> — *Phillip Owens*

scientists have mapped soils based on taxonomy. Owens advocated creating soil maps based on function. He developed a digital soil mapping technology to create detailed maps based on functional properties, such as carbon content, soil depth and crop suitability. Computer algorithms find repeatable patterns in the terrain based on land topography to fill in gaps where data is limited. He's using the technique in Colombia and Central America to create digital maps that scientists can use and improve upon as more data becomes available. "I really believe these [digital soil mapping] tools are going to change the future of how we manage," Owens said. "We have to have information at the level where people are making decisions, or we'll have very little impact on a larger scale."

Participatory Approach

Although big data is creating new opportunities, don't forget the value in "little" data, several presenters urged.

Traditional data gathering methods also provide invaluable insights and direction. Presenters described projects that merge large datasets with local knowledge, a participatory approach that generates locally relevant and creative solutions.

In El Salvador, Catholic Relief Services supplies communities with satellite images to help them solve their own agricultural problems, said the nonprofit organization's Paul Hicks, during the View from the Field Panel. The project, Mapeo Amano, asks the community to identify important landscape characteristics, such as springs or other water resources, directly onto inexpensive satellite images or aerial photos. The activity enables people to think about problems from a larger landscape perspective, which encourages finding solutions on a wider scale that involve stakeholders beyond the community.

In 2014, El Salvador suffered an extreme drought, and farmers wanted to be more resilient. The participatory approach is helping to restore watersheds and improve water recharge, harvest available water and improve soil and crop management, Hicks said. "It's incredibly empowering, and then very useful in terms of getting people's interest in supporting these community-led activities."

In a different setting, more than 1,300 Nebraska farmers, representing 1.76 million acres, plus crop consultants, resource managers and others, are working collaboratively with UNL to reduce water withdrawals and conserve energy. The Nebraska Agricultural Water Management Network, established in 2005, integrates research science and extension outreach to enhance the exchange of ideas, knowledge and data between the local and research communities to improve water management in the field, said UNL's Suat Irmak, the network's director.

Irmak described the network's extensive research projects and outreach efforts during the Data from Field to Global Scales Panel. The network helps farmers

From top left: Christopher Neale, Michael Farrell, Michael Forsberg, Martha Anderson and Ian Cottingham.

better manage irrigation through soil water content monitoring, including incorporating evapotranspiration and soil moisture measurements on their farms. Participants reduce irrigation withdrawals by an average of 2.2 inches and collectively have saved more than an estimated $80 million in energy costs from 2005 to 2012.

Citizen Scientists

Farmers — the ultimate stewards of 70 percent of the world's freshwater resources — may be obvious constituents to incorporate into agricultural research, but other community members can also play important roles.

Several presenters described the need to "ground truth," or verify, data collected at regional and global scales. Ground truthing collects location-specific data to calibrate remote sensing data, for example. But presenters also discussed the importance of consulting local experts to verify accuracy or improve analysis, as well as using citizens to gather data.

UNL's Mark Svoboda, for example, said input into the U.S. Drought Monitor from local experts, considered a weakness by

> "The idea was to set an entire watershed in motion by leveraging the power of photography as both a tool and a storyteller for education and research."
>
> — *Michael Forsberg*

some, is in fact its greatest strength. "Getting that local buy-in, I think, is what made the Drought Monitor what is it today, more even than the evolution of the products that go into it," Svoboda said, during Data to Better Understand Climate Systems.

Fellow panelist Henry Reges, of Colorado State University, coordinates a national network built entirely of local volunteers, or citizen scientists. The Community Collaborative Rain, Hail and Snow Network, or CoCoRHaS, has cultivated a contingency of 20,000 volunteers who record daily rain, hail and snow data from their backyards at the CoCoRHaS website. Collectively, the network constitutes the largest source of daily precipitation measurements in the U.S.

The National Weather Service and others use CoCoRHaS data to ground truth radar estimates and improve weather forecasts. Other agencies and local governments use the data to monitor snowpack, provide river forecasts, inform agricultural decisions and better understand storm impacts, among other uses.

Another project not only gives scientists and the public a new perspective on an important agricultural watershed, but also benefits from their input. Nebraska conservation photographer Michael Forsberg and filmmaker

Mike Farrell, of Nebraska Educational Telecommunications, direct UNL's Platte Basin Timelapse Project, which placed more than 40 cameras along the entire length of the U.S. Heartland's Platte River watershed. The cameras take a picture every daylight hour, providing a visual timeline to better understand the influence of agriculture, municipal water supplies, geological processes, restoration projects and other activities along the watershed.

"The idea was to set an entire watershed in motion by leveraging the power of photography as both a tool and a storyteller for education and research," Forsberg said. With nearly 1 million images, the team's focus has shifted from building the infrastructure to telling stories and building a community around the watershed, Farrell added. They are creating documentaries, developing learning programs for schools and enhancing the website.

UNL's Ian Cottingham has developed user-friendly software that enables researchers and the public to use the photos to create videos, add scientific datasets, annotate or manipulate images and create their own narrative about the river, which educates others and adds to the collective knowledge about the Platte River region.

Chapter 5: Global Yield Gap and Water Productivity Atlas

Farmers' yields rarely reach their full potential. Diseases, limited water and less than optimal management decrease yields. Knowing the gap between actual and potential yields is a key ingredient to sustainably intensify agriculture on existing cropland, said UNL's Ken Cassman. He heads the Global Yield Gap and Water Productivity Atlas, an analytic tool that estimates exploitable gaps in yield and water productivity for major food crops worldwide.

Unlike other efforts to estimate yield potential, the atlas uses an innovative bottom-up approach. International collaborators, led by UNL and Wageningen University in the Netherlands with support from DWFI, developed universal protocols that scale up site-specific data to regional and global levels. This consistent approach provides locally relevant yield gap information, as well as the ability to assess yield potential on national and regional levels and to make comparisons across climate zones. Decision-makers can

Ken Cassman

use the information to identify regions with the greatest potential to produce more food sustainably, limit cropland expansion and use resources more efficiently, Cassman said.

The atlas is publicly available via an interactive, web-based platform. To date, yield gap analyses have been conducted in 20 countries, half of them in Sub-Saharan Africa. Wageningen University's Martin van Ittersum and UNL's Patricio Grassini and Nicolas Guilpart detailed the methods, data and website behind the atlas during the Global Yield Gap and Water Productivity Atlas Panel.

Countries are stratified into climate zones. Then local agronomists identify major crop production areas and collect local weather and soil data and cropping system information. Simulation models estimate yield potential under unlimited and water-limited, or rainfed, conditions. The results are then scaled up to climatic zone and national levels.

Lack of appropriate, publicly available data is a problem in some countries, Grassini said. In nine target Sub-Saharan countries, for example, only 13 percent had at least 15 years of daily weather records considered ideal. In those cases, the atlas' protocol provides measures for using limited data. As data improves, analyses can be updated.

Other panelists described their use of the atlas:

• Australia's wealth of data provided the opportunity to assess the atlas' protocols for limited data, said Zvi Hochman, of Australia's Commonwealth Scientific and Industrial Research Organisation. Actual yield results for both were nearly identical and within statistical range for potential yields. "I think overall, we can say that this work adds strength to the validity of the global yield gap protocol," he said. Hochman and his team are using the atlas to compare countries of similar climate zones to gain insights into how to improve Australian food production.

• Although Argentina exports between 65 percent and 90 percent of its staple crops, Juan Pablo Monzon, of Argentina's National Scientific and Technical Research Council, and his colleagues used the atlas to determine if the country could improve yields enough to increase its food exports significantly. Results indicate that Argentina achieves between 60 percent and 70 percent of its potential water-limited yields. By reaching 80 percent of its water-limited yield potential, Argentina could significantly increase its share of global trade. "Closing the gap in an export country like Argentina may have a huge impact on global food supply, and of course on price because it would help keep the price at a reasonable level," Monzon said.

• In contrast, Ethiopia's and Ghana's yields are significantly below potential. Both countries expect populations to double by 2050, and researchers used the atlas to investigate future food security. Kindie Tesfaye Fantaye, of the International Maize and Wheat Improvement Center in Ethiopia, and his colleagues determined that by closing the water-limited yield gap to even half of potential, Ethiopia would be able to feed its population in 2050. "If we dedicate resources, it's within reach," Tesfaye said, adding that the atlas provides an important incentive for lawmakers and others to invest in Ethiopian agriculture.

Wageningen University's Lenny van Bussel and her colleagues also determined that Ghana could be cereal self-sufficient in the future by closing its yield gap to within 30 percent of potential. However, to do so in the Guinea Savanna agricultural zone would require cropland expansion.

• In Sub-Saharan Africa about 40 percent of rice is imported, said Kazuki Saito, of the Africa Rice Center. He and his colleagues assessed the potential for Africa to become rice self-sufficient and found that, using current technology, self-sufficiency isn't possible without cropland expansion.

Governments will have to find the right balance between expanding areas for rice cultivation and imports, Saito said. Additional yield gains could be made by developing new technologies and by accelerating yield growth rates, a key factor affecting upper yield limits.

Knowing the gap is just the first step, Cassman emphasized. The atlas identifies opportunities to reduce the yield gap, but decision-makers must also integrate the political, social and economic constraints and opportunities to develop a strategy appropriate for each nation. However, atlas analyses provide valuable evidence and information to help motivate change.

"[Atlas researchers] are now giving us hope that we can actually, if we do what they have suggested, we can feed these 9 billion people by the year 2050," said Bashir Jama, of the Alliance for a Green Revolution in Africa, during the Closing Panel.

Kazuki Saito

Chapter 6: Public Health Data Tools

Data's revolutionary power is also at work in the public health sphere, as a panel of public health experts illustrated. Human genome sequencing is yielding clues to cancers and other diseases. Large datasets have improved the effectiveness and timeliness of surveillance systems to detect and predict disease outbreaks. New computer-based tools can identify links between air quality and respiratory disease, analyze social networks to help predict the spread of HIV infections, and find associations between health conditions and a human host's resident gut microorganisms. In turn, governments have the information they need to make better health policies and improve access to healthcare.

Ali Khan, of the University of Nebraska Medical Center, also described the Internet-based technologies, from social networking sites to web searches and wikis, that harness the public to provide fast and timely information and as a means for disseminating information. Google Flu Trends, for example, analyzes clusters of search terms by region to predict flu outbreaks in the U.S. faster than traditional means. Cellphones are also a powerful tool for disease surveillance in hard to reach areas. Following the 2010 earthquake in Haiti, for example, cellphones helped officials obtain death counts and identify cholera outbreaks.

Emmanuela Gakidou, of the University of Washington, described a more systematic tool that quantifies the comparative magnitude of health loss for all major diseases, injuries and risk factors by population and over time. The web-based Global Burden of Disease project, a global collaborative effort led by UW, contains data on 323 diseases and injuries and 72 risk factors in 188 countries from 1990 to the present.

Emmanuela Gakidou

The project enables public health experts, the public and governments to compare the effects of different diseases that kill people prematurely and cause ill health, helping decision-makers to better meet health challenges. For example, the extensive database demonstrates that diarrhea, about 85 percent of which is attributed to lack of safe water and sanitation, is one of the biggest contributors to the global burden of disease. Gakidou urged conference participants to contribute their expertise to further improve the project's data.

Part Three

Neil Palmer, CIAT

Challenges and Risks
Chapter 1: The Role of Institutions

Although technology tools have been available for use in water management and agricultural production for several years, many conference leaders agreed that we are still a long way from truly harnessing the information and making effective use of it at all scales and across sectors.

"The core problems aren't necessarily around the technology itself," said IWMI's Jeremy Bird. "How are we going to get that onto the agenda of the policymakers, such that they can become champions of change and use some of this data to address some of these problems?" What information is needed to change institutional structures to improve management? What data is needed to influence behavior, whether it's encouraging technology adoption or changing bureaucracies? How can we use information to target investments appropriately?

Policy and Governance

The role policy plays in managing water scarcity and food production was illustrated during discussions regarding aquifer overpumping. India's severe groundwater depletions are due, in part, to electricity subsidies that encourage overpumping. And in California, farmers continue unrestricted pumping despite a stressed groundwater supply from four years of extreme drought. Even in a relatively wet year, California overpumps groundwater, said Peter Gleick, of the Pacific Institute, during the Data to Better Understand Climate Systems Panel.

California's plight demonstrates how data can propel policy change, and how governmental action can create the impetus for data gathering. Recently, the satellite-based Gravity Recovery and Climate Experiment, or GRACE, dramatically demonstrated just how badly California has already overpumped its aquifers. The data

Peter Gleick

helped push the state to pass groundwater monitoring legislation, Gleick said. Without detailed, ground-level information, it's difficult to know how much groundwater is pumped from the aquifer, the aquifer's overall health or how to use water more efficiently on crops. "The lack of data should not be a reason for inaction," he emphasized. "Solutions should be pursued more aggressively even while we debate, broadly, the future of water."

While Californians have taken their first steps to regulate groundwater statewide, panelists in the Implications of Metering for Agricultural Water Management Session described other states' and countries' use of policies — from metering water to Australia's highly structured water markets — to successfully promote the economic vitality of irrigated agriculture even during droughts. The State of Nebraska, for example, has been regulating groundwater for more than 40 years to help maintain aquifer levels, despite having the most irrigated acres in the U.S.

"Data collection, planning, modeling and metering required to create water markets don't always make for happy farmers, but with great data comes great markets, good environmental outcomes and, ultimately, farmers with more financial and agronomic opportunities."

— *Richard Bootle*

The Upper Big Blue Natural Resources District, one of 23 districts created in 1972 to manage resources at watershed levels, began requiring metering on new wells in 2004, said Rod DeBuhr. Metering encourages farmers to use less water, helps identify regional differences in irrigation and helps predict where problems may arise in the future. Efficient center pivot irrigation has helped maintain water tables, and water use rates have declined significantly since the 1970s, he said.

Dry and drought-prone Australia has led the world in water management reforms, creating an innovative water market system that allows farmers to adjust in times of drought. "The essential building block of any good market is measurement, and for water that means metering wherever you can," said Richard Bootle, of Bogan Farms and Lawlab.

The Australian government made water an asset, which can be traded through water accounts, much like bank accounts. Each year, the government determines allocation amounts. Farmers use information about water usage, weather, crop and water prices to decide whether to irrigate a crop or not plant and instead sell their water allocation. This market approach facilitates water use where it's needed most and suspends agriculture when necessary until water conditions improve.

"Data collection, planning, modeling and metering required to create water markets don't always make for happy farmers," Bootle admitted. "But with great data comes great markets, good environmental outcomes and, ultimately, farmers with more financial and agronomic opportunities."

Panelists acknowledged that unhappy farmers worldwide have found inventive ways to circumvent meters and water restrictions, and they described ways in which they work to overcome resistance. In Oman, for example, where the Al Suwayq coastal aquifer has been overpumped for decades, the government is introducing groundwater flow meters. A law allows for water quotas, but implementation has been difficult, and the government is working extensively with farmers to help educate them about groundwater issues, said Slim Zekri, of Sultan Qaboos University. Solutions go beyond quotas, he added. Farmers should be incentivized to introduce smart irrigation systems and recharge dams and be allowed to switch saline farmland to urban uses.

China, also facing significant aquifer overpumping, hasn't yet instituted water restrictions to give farmers time to adjust to metering, said Wolfgang Kinzelbach, of ETH Zürich. Implementing the right

Richard Bootle

incentives is key but so, too, is enforcement. In time, farmers will accept quotas, he said. To work, however, farmers' incomes shouldn't drop, which is possible, at least initially, only through subsidies that encourage less water use.

Northern Texas adopted metering and other rules in the mid-1990s to address serious aquifer depletion, but farmer resistance shelved implementation for more than a decade, said Steve Walthour, of the North Plains Groundwater Management District. In 2007, the rules were changed to require metering on new wells, but allow existing wells to report water use based on alternative methods, including electricity and pivot use measurements. Because the district worked with the community to find solutions, nearly every producer reported their rates the first year, Walthour said.

Greater appreciation for metering came after three farmers offered their farms to demonstrate that metering and limiting water can improve yields and conserve resources. "I think it had to do with farmers working with farmers to get there," Walthour said. "The biggest thing we have to deal

with as a district is how do we educate the producers in our area to continue to produce well into the next 50 or 100 years? The only way we're going to stay economically viable is to know what our datasets are."

Margaret Catley-Carlson, of the Canadian Water Network, said during the Closing Panel that these regions all faced challenges in implementing metering and water use regulation. But they demonstrate how, if done properly, metering data then contributes to the knowledge that helps farmers accept change — a powerful lesson in governance.

Public versus Private Data

Data has become a commodity. The commodification of personal data raises privacy concerns that can lead to limiting access to data and information. For some countries, national data gathered by foreign entities is particularly concerning. However, the high cost of gathering and analyzing data hinders national research and policymaking efforts in resource poor countries. The conference discussed the roles and responsibilities of the public and private sectors in managing data and investing in value-added analyses.

There's a distinction between raw data, information and a recommendation based on that information, said Andy Smith, of Valley Irrigation, who moderated the Innovations in Irrigation Data Systems Panel. Where in the value chain is the data intercepted, and what intellectual property is associated with each layer in that chain? "By and large, we're, in agriculture, still living in the Wild West," he said.

UNL's Ken Cassman argued during the Trends in Water and Agriculture Session that public funding of climate and natural resource data could help answer important questions about climate change, agricultural decision-making and productivity. The public sector should provide real-time and historical weather and water resources data, as well as crop yields, soil productivity and

From left: Ronnie Green, Lee Addams and Chris Tingle.

aquifer levels, among other data types, he said. Instead, the U.S. is largely disinvesting from gathering publicly available data, particularly weather data.

"We need both," Cassman said. "We need the private sector to leverage public sector weather data… The bad thing is if the public sector divests so much that only the private sector can develop its own network and not only provide value-added weather data, but they're the only ones with the weather data."

The growing divide between public and private research data was also raised during the Industry Leaders Panel. From Syngenta's drought-resistant seeds to Valley Irrigation's development of variable rate irrigation, the private sector has capitalized on the data revolution to develop valuable technologies and services, panelists said. The issues and resulting products are so complex, however, that collaborations between private companies and public institutions, such as universities, are necessary to develop new products. "As critical as the science is, I think we all have to acknowledge that nobody can do this by themselves," said Chris Tingle, head of water optimization at Syngenta, an agrochemical company. "How do we transform information into a recommendation, I think, is the crossroads that we're at. And a number of industry partners are working together to help solve that."

CGIAR's Frank Rijsberman said he's amazed at the speed with which the private sector acquires and manages large amounts of data and would like to see more public-private partnerships to close the gap between what the public and private sectors have to offer.

Philanthropy's Influence

Philanthropy has long influenced development, but its impact will be even greater in the next 40 years with eight to ten times more wealth going into philanthropy than in the entire 20th century, said Jeff Raikes. Raikes moderated the Philanthropy and Funders Panel.

Philanthropy shouldn't interfere with the public sector, he said. Instead, it should identify gaps where the public sector doesn't have the means or won't take the risk, but the private sector doesn't see a market opportunity. This catalytic philanthropy steps in to help develop an intervention that others won't. Once the activities have been scaled up and either the market or public funding can sustain it, then philanthropy should step back.

Panelist Raymond Guthrie, of the Skoll Foundation, agreed. Skoll invests in social entrepreneurs that it believes can help drive large-scale change. Evidence must suggest

From left: Jeff Raikes, David Bergvinson and Raymond Guthrie.

that an innovative approach is already driving an impact and is sustainable. One successful example is the One-Acre Fund, which works with smallholder farmers in East Africa to develop strategies for improving crop yields and partners with national governments to use those innovations to help farmers.

Skoll uses data to track progress and is flexible enough to adjust its grants to support the end goal, Guthrie said. "We only view failure if we see data and don't right the ship." They also seek to allow nongovernmental organizations access to data to improve their own projects.

The Gates Foundation uses a different approach, said David Bergvinson. Sustainable solutions for smallholder farmers means tying them to equitable markets, so the foundation looks for private-public partnerships in market integration and in technology development to help smallholder farmers lift themselves out of poverty. To help smallholders take advantage of data more must be done to support farmers through private sector services that help them integrate into the

marketplace, Bergvinson said. Farmers will receive services for the data they provide from their farm. "That business model holds a lot of promise in making agriculture a commercial enterprise, even for smallholder farmers," he said.

IDE, a nonprofit organization that focuses on getting technology to smallholder farmers, helps facilitate building markets, said Stuart Taylor, during the Data from Field to Global Scales Panel. "What are the businesses that offer products and services to the small-scale farmers? And what can we do to ease some of the bottlenecks?"

The 30-year organization recognized that it wasn't enough to get irrigation technology into the hands of farmers. Supply-chain issues, markets, credit mechanisms and other constraints also must be tackled. Because they operate in data-poor environments at the field level, iDE decidedly works at the small data level: talking to farmers directly, Taylor said. He described a study that used data to monitor and evaluate a program in Zambia to identify constraints for taking the program to a market level.

DWFI and International Water Management Institute establish partnership

The Daugherty Water for Food Institute signed a memorandum of understanding with the International Water Management Institute at the conference. The agreement reflects a strategic partnership to facilitate cooperation, global capacity building and collaboration in the areas of water and food security. DWFI and IWMI are committed to work together to develop knowledge and technological advances to enhance water productivity, educate professionals and develop human capacity in the areas of water management and food security and to develop constructive water policy.

IWMI Director General Jeremy Bird (left) and University of Nebraska Interim President James Linder sign a memorandum of understanding October 20, 2014. Witnessing the signing is from left: Roberto Lenton, Christopher Neale, Ronnie Green and Peter McCornick.

Chapter 2: Social Barriers

Building institutional capacity and encouraging adoption of new technologies requires understanding cultures, behavior and other social characteristics. Yet, those factors are often overlooked and little understood, several presenters said. The significant gap in social knowledge leads to failed programs, ineffective institutions, mistrust, poor communication and misuse of funds.

"If we're going to create and identify and enable change in agricultural development for smallholder farming systems, I think it's equally important to put effort into the social and human dimensions of agricultural systems," said Jennie Barron, of the Stockholm Environment Institute, during the View from the Field Panel. To date, big databases fail to factor in human dimensions, such as gender, governance systems, inequity and decision-making. Though more difficult to collect, this information is vital to turn data into knowledge that supports behavior change and improves agricultural systems.

Gender Barriers

Women are increasingly involved in agriculture due, in part, to men leaving home to find work elsewhere. The feminization of agriculture puts more responsibility for global food security on women. Yet institutionalized gender discrimination restricts many, if not most, women from accessing extension services, credit and other critical resources. Allowing women equal access to resources would increase agricultural production up to 30 percent and reduce hunger by up to 17 percent in developing countries, said IWMI's Jeremy Bird.

He mentioned one effort to incorporate gender data into agricultural models and planning. An online gender map of Sub-Saharan Africa, developed by IWMI and the International Food Policy Research Institute,

solicits gender information from extension workers, researchers and practitioners knowledgeable about farming systems at county, state and district levels. Bird encouraged the audience to contribute to the Gender Mapper.

Margaret Catley-Carlson, of the Canadian Water Network, said during the Closing Panel that the Global Yield Gap and Water Productivity Atlas and other database systems are missing important inputs related to gender, land titles, lack of roads and health problems, among others. "All of those have to be factored into the mix when you're dealing with the poorest farmers because the choice of seed and the agricultural inputs are far from being the main factors determining whether the yields are going to be met or not," she said.

From left: Paul Hicks, Phillip Owens, Dewingong Columbus Leke and Jennie Barron.

Data Sharing

Much of big data's potential benefits stem from accumulating data from a wide range of sources, whether personal information, farm data or DNA codes, to find connections and identify trends. In turn, these aggregated data and analyses are intended to help individual farmers, companies, researchers and governments.

However, concern over data privacy and ownership make farmers and others reluctant to share data, several presenters said. U.S. farmers, for example, worry their data will be used to help their neighbors, said Syngenta's Tingle. The company, which uses farmer data to make product decisions, takes a transparent approach with farmers, ensuring anonymity, he said.

For smallholder farmers, trust is also an issue, said Bergvinson, of the Gates Foundation. "It's an industry of trust, and we don't want to compromise that trust by not managing personal information of farmers to where it's exploited against the goals or vision of the smallholder farmers." The agricultural community must consider how data is used securely and equitably and in a manner that returns value to smallholders, he said.

Sharing data can also lead to its misuse. "Sometimes [researchers] produce data that isn't necessarily super welcome," Barron said, which can lead to cherry-picking or ignoring data to suit needs.

Even sharing information among government ministries is challenging and leads to inappropriate programs, noted several presenters. "If they don't remove all of these bottlenecks, we won't be making progress," said Dewingong Columbus Leke, of the Nigerian Federal Ministry of Agriculture and Rural Development.

The research sector is also guilty of not sharing data, participants acknowledged. Much raw research data is lost after publication and, when data is divorced from the original context, it's gone, added hydrologist John Gates, of Climate Corporation, from the audience.

Social Solutions

A solution raised repeatedly in diverse contexts was to engage farmers, governments and the public. Collaborations and effective communication go far toward building trust, creating reliable data and developing solutions and programs that succeed.

Paul Hicks

Nongovernmental organizations — and scientists — are sometimes guilty of using farms as laboratories to test ideas, and may even initiate strategies for another country without consulting the government, said Paul Hicks, of Catholic Relief Services. Before proposing studies or projects, understand the problems and identify what information locals need to work toward solutions, he advised. Engaging the government and aligning donor funding toward national priorities would more efficiently use resources than is currently happening.

With the increasing reliance on data, ensuring its reliability is critical. For those working in other countries, the local environment and data may be unfamiliar, warned Columbus Leke, so it's particularly important to recognize that unfamiliarity, seek out local guidance and use data within the proper context.

Bergvinson said that a participatory approach has helped the Gates Foundation reach more than 6 million farmers to better understand what they want in new varieties. That awareness helps drive decisions and serves to create awareness and demand for new products.

 In addition, farmers should own their own data, and the public and private sectors are entrusted with responsibly managing that data, several participants said. Transparency is critical, so farmers can make informed decisions, said James Krogmeier, of Purdue University. He also suggested that universities provide their own data clouds to make research data more widely available.

Governments and prominent organizations are calling for open data to support agricultural development, and some make their data publicly available, such as the Agricultural Model Intercomparison and Improvement Project, or AgMIP, and HarvestChoice, Bergvinson said. The Gates Foundation also helped develop Global Open Data for Agriculture and Nutrition, an initiative that supports making agricultural

and nutritional information available and usable for use worldwide.

Several participants said they see continued roadblocks in the years ahead due to farmers' lack of trust, but others suggested that as young people enter farming, they'll be more willing to share data. And the growing technological focus in farming is beginning to attract more young people to farming, several participants noted.

Researchers should also engage the public, said AGRA's Bashir Jama, during a discussion in the View from the Field Panel. Policymakers often respond more to the media and public response than to scientists. Yet little time is invested in synthesizing knowledge and communicating to the public in meaningful ways.

Lead with the story, several presenters advised. "Don't beat the politician over the head with the data," Barron said. "You start out with the story about why it matters. They'll begin to listen to the story." Catley-Carlson added that communicating solutions is often better received than dwelling solely on problems.

Margaret Catley-Carlson

Chapter 3: Water, Food and the Public's Health

The agricultural community's goal focuses on doubling food production to meet the demands of a growing global population. But increasing available calories isn't enough, said CGIAR's Frank Rijsberman. "We have to look more at health and nutrition sensitive agriculture," he said. "That means not just how many calories we get, but do people also have the micronutrients, the iron, the zinc, the vitamins?"

To help address that issue, Ali Khan, of the University of Nebraska Medical Center, and a panel of public health and child development experts, shared their perspectives on the relationships among food, water and health.
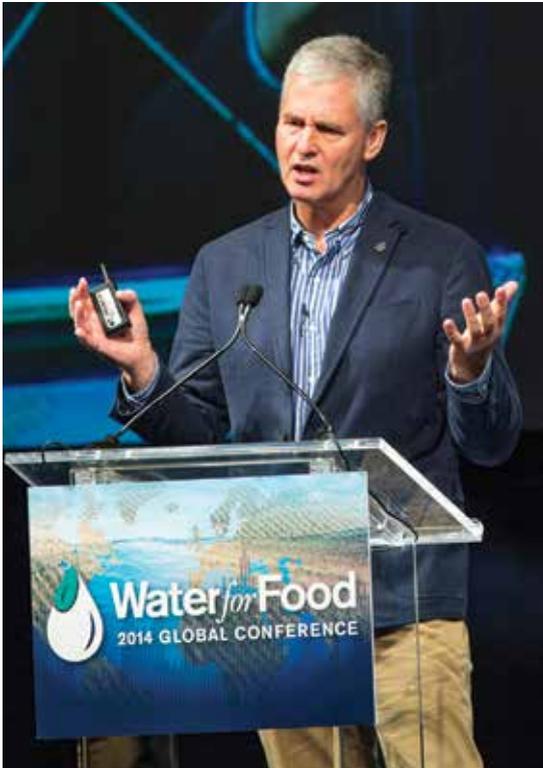
One Health

Human, animal and environmental health are intrinsically linked, but at some point, the three fields became distinct disciplines that rarely connect, said Peter Rabinowitz, of the University of Washington (UW). Though the idea that human health is affected by animal and environmental health — the One Health concept — isn't new, recent global changes have led to renewed focus on these interconnections.

One concerning change is the increase in zoonotic or vector-borne infections, which account for 70 percent of global disease outbreaks. The Ebola outbreak devastating several West African countries in late 2014,

Neil Palmer, CIAT.

The floodplains of the Black Volta River in Ghana.

"We have to look more at health and nutrition sensitive agriculture."

— *Frank Rijsberman*

for example, had moved from an animal host to humans. Eating bush meat, a practice that increases when crop production is insufficient, is one cause of zoonotic outbreaks, Rabinowitz said. In turn, the consequences can ripple out to affect food security, Khan added. A survey found that 47 percent of farmers in Sierra Leon were disrupted by the recent Ebola outbreak, and rice production was down 10 to 15 percent in the Ebola affected region.

Environmental, animal and human health are also connected through waste generated by animal production, Rabinowitz said. As the human population increases so, too, do animal populations, particularly as rising incomes increase meat consumption. In the past 50 years, for example, chicken populations have increased at a much steeper rate than the human population.

Raising animals fast enough to meet demand has intensified animal production, leading to concentrated waste and disease

outbreaks. Waste or wastewater used to fertilize or irrigate crops can run off into water supplies, carrying pathogens and harmful nitrates. Controlling the animal waste stream efficiently remains a major problem, Rabinowitz said.

In many low-income countries, people and animals share water resources. About 10 percent of all ill health and disability globally can be attributed to unsafe water and sanitation for children under five, said UW's Emmanuela Gakidou. Despite advances, 900 million people remain malnourished. In most African countries, access to safe water is below 20 percent, though India suffers the highest burden of disease and disability from unsafe water.

Surviving, but not Thriving

Very young children are especially vulnerable to the effects of poor water quality, said UNL's Helen Raikes. More than 7 million children under five die

James B. Milliken Award Recognition

The Daugherty Water for Food Institute recognized James B. Milliken's role in establishing the Daugherty Water for Food Institute at the conference banquet. The former University of Nebraska president and current chancellor of The City University of New York was honored for his visionary leadership, which helped transform DWFI from a kernel of an idea in 2009 to a global institute focused on achieving water and food security. With the generous support of the Robert B. Daugherty Charitable Foundation, Milliken guided the development of DWFI to leverage the University of Nebraska's talents and help create a legacy that is important not only to Nebraska, but also to the world. Remarks were given by James Linder, NU interim president, and the award was presented by Mogens Bay, chairman of the Daugherty Charitable Foundation.

From left: Roberto Lenton, James Linder, James B. Milliken and Mogens Bay.

Helen Raikes

each year, mostly from preventable causes, and an estimated 200 million are at risk of not developing to their full potential, many because of malnourishment.

The early stages in a child's growth lay the foundation for later stages of development, Raikes said. Brain development and gut health are established during the first few years. Improving diets can address some nutritional deficiencies, but lack of clean water causes diarrhea, which leads to malnutrition. Research suggests that even bacterial levels that don't cause overt diarrhea can reduce the gut's ability to absorb nutrients. So even children receiving proper nutrition may be malnourished from unsafe water. Poor nutrition is linked to mortality, stunting and poor cognitive development.

An astounding 85 percent of the impact of climate change will be to children, primarily through diarrhea, undernutrition and malaria, said UW's Kristi Ebi. Climate change increases the risk of diarrheal disease because pathogens proliferate faster in warmer temperatures and wash into waterways during heavy rains, while droughts encourage people to use pools of standing water where pathogens or disease vectors reside.

In addition, climate change will reduce food production's potential gains, thereby increasing the number of undernourished and stunted children by 2050. "Climate change is going to reduce and may even eliminate all of the gains that we've made with development," Ebi said. "It's going to become more difficult in many regions to achieve food security."

Albert Gonzalez Farran, UNAMID

Poor Diets

Obesity and chronic diseases due to poor diets are additional global risk factors, responsible for about one-tenth of all illness and death worldwide in 2013, Gakidou said. Unlike diarrheal diseases, dietary risk is concentrated in areas with safe water and sanitation. Eastern Europe is particularly vulnerable, with 20 percent of deaths and disability attributable to bad diets.

A healthy diet of minimal risk requires 2,000 daily calories, half of which are protective and a third neutral. Globally, however, diets contain nearly a third more calories, only one-third of which are protective and nearly 20 percent are harmful. Global food production doesn't match a low-risk diet, overproducing red meat by more than 550 percent, while producing only half the milk needed, Gakidou said. "One of the areas where our two fields can work together is how do we actually come up with and produce food that is available for everybody and is done in a sustainable way, but also does not lead to ill health?"

Peter Rabinowitz

Working across Disciplines

Panelists agreed that a multidisciplinary approach is needed to address health problems related to food and water. While much data exists on human health and animal health, environmental health data is lagging, Rabinowitz said. And the data that is available isn't shared among these three spheres of health. How do we pool data and strategies to avoid unintended consequences and maximize all three? he asked.

Rijsberman said the CGIAR is beginning to address food quality, not just quantity. Can we build nutrition into the plants? he asked, citing current examples, such as golden rice, a product that incorporates a carrot gene into rice to reduce vitamin A deficiency.

Finding ways to engage policymakers is also critical, panelists agreed. From the audience, Jeff Raikes suggested the need for research that provides evidence countries need to understand the impact that cognitive impairment in children has on their future

economies. "If you can help them understand how they are suboptimizing their human resource, then you get the finance minister and the president or prime minister saying we have to invest in these things," he said.

Thomas Novotny, of San Diego State University, who moderated the panel, agreed, adding that the research community needs a better understanding of policies and incentives, how big agencies are influenced and how donors can influence governments. "It's not just looking at diseases; it's looking at the entire system of their determinants and opportunities for intervention."

Khan urged audience members to include health variables in their projects' evaluation criteria, to seek opportunities to influence health policies and to include public health experts in their activities. "People aren't unhealthy because they're poor; they're poor because they're unhealthy," he said. Take care of their health needs, and people can earn an income.

Part Four

Conclusion

The data boom may not have revolutionized agriculture yet, as Jeff Raikes suggested in opening remarks at the conference, but participants demonstrated that big — and little — data is making inroads in countries around the world.

Each year, the Water for Food Global Conference strives to bring together a diverse mix of experts working at all scales and arenas of the water and food sectors with the goals of sharing ideas and encouraging unique partnerships. This year, with the help of thought partners IWMI and the Global Water Initiative, we paid particular attention to the opportunities the data revolution presents to smallholder farmers and low-income countries.

To that end, the conference explored in-depth the potential of a variety of data tools to aid smallholder farmers, from genomics and remote sensing to soil mapping and cellphones. And we heard about several outstanding programs for smallholders that are having real impacts at community and national scales. But the conference also illustrated the special challenges facing smallholders, in part through discussions about trust and access, but also by what was missing: for large-scale farmers, discussions are dominated by robust answers; for smallholders, they remain primarily questions. High-tech tools may be viable for poor farmers, as Raikes fervently suggested, but finding a way there will require everyone's involvement.

By bringing research, the public sector and private industry together, the conference bridges divides, encouraging the conversations and sharing that will lead to more answers. We encourage even greater commitment and focus from all sectors to helping resource-poor countries develop the technological tools and institutional structures they need to feed their populations in the future.

Working together is key. Yes, coordinating among public, private and philanthropic sectors is challenging. Too much bureaucracy can slow

X. Fonseca, CIMMYT

decisions, technologies don't often work together and lack of data sharing hinder progress. These problems can be overcome.

Also key is including farmers, governments and the public in our work, a point raised frequently throughout the conference. Creating data alongside farmers and governments helps build trust, ensures more reliable data and is more likely to result in useful knowledge that translates into better decisions and policies. And public opinion matters to policymakers, so engaging the wider society cannot be overlooked.

Another critical, related solution raised in a variety of contexts is investing in education and extension. Gathering and analyzing complex data systems requires specialized expertise currently in short supply, so training young scientists in both developed and developing countries to analyze data is needed. Farmers and government agencies also need support to use data to improve their operations and decisions. Building capacity should be a priority moving forward.

The 2014 Water for Food Global Conference illustrated the many opportunities created by the data revolution to improve water and food security, but also raised the many challenges that remain before we can take full advantage of this new era of data to benefit both large and smallholder farmers.

Appendix

Plenary & Concurrent Session Presentations

Monday, October 20, 2014

Plenary Address

Jeff Raikes, Co-Founder, Raikes Foundation; Board Member, Robert B. Daugherty Water for Food Institute at the University of Nebraska
A Small(holder) Revolution: Harnessing Data for the Poorest Farmers

How can we apply the knowledge and insights gained from the data revolution to radically change the world? Jeff Raikes explored how data can transform smallholder farming practices to improve quality of life and increase global food security. In particular, he examined using data to reduce global demands on limited water resources by improving crop breeding, driving policy change and guiding more water efficient agronomic practices.

Plenary Address

Frank Rijsberman, CEO, CGIAR Consortium, France
How Big and Little Data Can Solve the World Water Crisis

In 2000, the World Water Vision attempted to lay out a scenario to move the water world from crisis to sustainability. What happened? How did the data revolution impact the vision? The world is in serious danger of exceeding its planetary boundaries. Climate change will affect water first and foremost, with impacts felt particularly in agriculture. Can big and little data help to regain stability? Can it help to provide a world of 9 billion people with healthy and nutritious food, while maintaining critical ecosystem services, in climate resilient, carbon-neutral agro-food systems?

Philanthropist and Funder Panel

Influential supporters of water and food issues discussed how the data revolution is affecting their giving decisions, including how they use data to evaluate the success of projects they fund. The panelists also highlighted the importance of philanthropy and corporate sponsorship in developing viable solutions to achieve global water and food security.

Moderator: Jeff Raikes, Co-Founder, Raikes Foundation; Board Member, Robert B. Daugherty Water for Food Institute at the University of Nebraska

David Bergvinson, Senior Program Officer, Crop Value Chains and Digital Design for Agriculture Development, Bill & Melinda Gates Foundation

Raymond U. Guthrie, Principal, Innovation Investment, Skoll Foundation

Industry Leaders Panel

Stakeholders from the private sector discussed how they use data to guide their research decisions and measure the progress and success of research outcomes.

Moderator: Ronnie D. Green, Vice President, Agriculture and Natural Resources, University of Nebraska; Harlan Vice Chancellor, Institute of Agriculture and Natural Resources, UNL

Lee Addams, Senior Vice President of Corporate Strategy, Valmont Industries Inc., Nebraska

Chris Tingle, Head of Water Optimization–North America, Syngenta

Water for Our Future: Seventh World Water Forum

A brief overview of the international planning process leading up to the World Water Council's 7th World Water Forum in South Korea, April 12-17, 2015.

Dale Jacobson, Governor, World Water Council

Plenary Address

Jeremy Bird, Director General of the International Water Management Institute, Sri Lanka
Big Data, Big Productivity Gains: Is it so Simple in Water Management?

Earth observations, computing power and mobile phone coverage offer a bewildering array of new opportunities to improve the management of water resources. They can be used across a range of scales and can increase the resilience of societies to external shocks, whether climate or market driven. The availability of processed data can short circuit current information gaps and restrictive practices. Although 'big data' alone may not be sufficient to revitalize agricultural water management, it is a necessary and promising step to rethinking priorities and targeting interventions.

A View from the Field Panel

Small-scale agricultural water management is fundamental to the food security of millions of poor farmers. Yet, many smallholder farmers have limited access to information that would enable them to make informed investment and management decisions. Panelists addressed the information needs of smallholder farmers, showcasing examples from Asia, Africa and Latin America where improved access to information is proving beneficial.

Moderator: Peter McCornick, Deputy Director General–Research, International Water Management Institute, Sri Lanka

Giriraj Amarnath, Researcher, Remote Sensing and Water Resources, International Water Management Institute

Jennie Barron, Senior Research Associate, Agriculture and Water Management, Stockholm Environment Institute

Paul Hicks, Water Resources Specialist, Catholic Relief Services, El Salvador

Dewingong Columbus Leke, GIS and Remote Sensing Analyst, Federal Ministry of Agriculture and Rural Development, Nigeria

Phillip R. Owens, Associate Professor, Pedology/Soil Geomorphology, Purdue University

Tuesday, October 21, 2014

Plenary Address

Robert T. Fraley, Executive Vice President and Chief Technology Officer, Monsanto Co.
2050: Agriculture's Role in Mitigating Global Challenges

Innovation will be key to sustainably addressing the challenges facing global agriculture. Increasingly, companies throughout the agricultural value chain are exploring ways to sustainably address the increasing demands of their customers. This work is pivotal as the world faces increased pressures from erratic weather and climate change, as well as the demands of a growing global population expected to reach 9.6 billion people by 2050. Robert Fraley explored these issues and addressed how data science is supporting and driving agricultural innovation and sustainable solutions.

Trends in Water and Agriculture Panel

New and complex sets of data, combined with innovations in how we use them, present significant opportunities to help ensure global water and food security. What are the data and information needs of farmers and how can we best implement them to make farming systems, both large and small, more sustainable? How can we ensure that the quality and accessibility of the data is sufficient to make informed decisions? The panelists addressed these questions while highlighting the dimensions of sustainability, the underlying reasons why humans develop technology during times of crisis, the challenges and opportunities of producing food in open and closed systems and insights gained from data acquisition and assessments related to the Global Yield Gap and Water Productivity Atlas.

Moderator: Christopher Neale, Director of Research, Robert B. Daugherty Water for

Food Institute at the University of Nebraska

Kenneth G. Cassman, Robert B. Daugherty Professor of Agronomy, UNL

Victor Sadras, Crop Ecophysiology, South Australian Research and Development Institute

Pasquale Steduto, Deputy Regional Representative for the Near East & North Africa Region, Food and Agriculture Organization of the United Nations, Egypt

Concurrent Session: Innovations in Irrigation Data Systems

A panel of industry experts explored how the data revolution is advancing the efficiency of agricultural irrigation. The discussion included how irrigation systems are being connected to data systems, how irrigation information is being moved and stored, how data helps farmers develop irrigation recommendations and how these processes are being integrated into comprehensive farm management information systems.

Moderator: Andy Smith, Director of Industry Relations, Valley Irrigation

Lance Donny, Founder and CEO, OnFarm Systems, California

James Krogmeier, Professor of Electrical and Computer Engineering, Purdue University

Mark Reiman, Learning Center Agronomist, Monsanto Co.

Terry Schiltz, President, AgSense, South Dakota

Concurrent Session: Impact of Water on Health: Issues, Opportunities and the Importance of Data

Panelists discussed how data is being used to predict emerging patterns of disease and pathogens in response to changing climate, understand how environmental factors influence early childhood development, assess the health impacts of development projects and study the human-animal-ecosystem interface.

Moderator: Thomas Novotny, Professor, Epidemiology and Biostatistics; Associate Director, Border and Global Health; Co-Director, Joint Doctoral Program in Global Health, San Diego State University

Kristi Ebi, Professor, Global Health, University of Washington

Emmanuela Gakidou, Professor, Global Health; Director of Education and Training, Institute for Health Metrics and Evaluation, University of Washington

Peter Rabinowitz, Associate Professor, Environmental and Occupational Health Sciences and Global Health; Adjunct Associate Professor, Allergy and Infectious Diseases, University of Washington

Helen Raikes, Willa Cather Professor, Child, Youth & Family Studies, UNL

Luncheon Presentation

Ali S. Khan, Dean, College of Public Health, University of Nebraska Medical Center; former Assistant Surgeon General, Centers for Disease Control and Prevention *Ensuring Water, Food Security and Public Health: Using BIG and Little Data*

Public health is confronted by unprecedented challenges today, including those associated with climate change and globalization. We have resources to address water and food insecurity: technology, people, policies, funds. And we also have information. We have big data that monitors, tracks and defines characteristics of groups of people. And we also have little data that defines the individual and his local community. By using big data, we can identify big problems. By using little data, we can verify these problems and make them more tangible and human. But neither type of data will solve the problem alone. Only by combining the two can we identify solutions and foster a culture of health in which food and water security is ensured — today and into the future.

Concurrent Session: Global Yield Gap and Water Productivity Atlas

Researchers explored how the Global Yield Gap and Water Productivity Atlas is helping farmers improve the productivity and sustainability of cropping systems around the world, providing practical solutions on the ground. The atlas is an innovative, map-based web platform used to identify existing farmland where significant gaps exist between actual and potential yields. Panelists led an interactive discussion on why the atlas is needed to improve global food security, including a demonstration of how it works and case studies highlighting the current size of the yield gap in several countries in Latin America, Sub-Saharan Africa and Australia.

Moderator: Kenneth G. Cassman, Robert B. Daugherty Professor of Agronomy, UNL

Patricio Grassini, Assistant Professor, Agronomy and Horticulture, UNL

Zvi Hochman, Senior Principal Research Scientist, Agriculture Flagship, Commonwealth Scientific and Industrial Research Organisation, Australia

Kazuki Saito, Principal Scientist and Africa-wide Rice Agronomy Task Force Coordinator, Africa Rice Center

Juan Pablo Monzon, Assistant Research Scientist, National Scientific and Technical Research Council (CONICET); Associate Professor, Agricultural Sciences, National University of Mar del Plata, Argentina

Kindie Tesfaye, Researcher, International Maize and Wheat Improvement Center, Ethiopia

Lenny van Bussel, Postdoctoral Research Associate, Wageningen University, Netherlands

Martin van Ittersum, Professor, Plant Production Systems, Plant Sciences, Wageningen University, Netherlands

Concurrent Session: Implications of Metering for Agricultural Water Management

Measurement of agricultural water use is increasing in both developed and developing world contexts. While metering offers potential economic gains and allows new types of policies to be implemented, it is also controversial and may be unpopular with producers. Panelists addressed the policy drivers and potential economic gains of metering, as well as the role of monitoring and enforcement and the potential unanticipated consequences of the practice. Case studies from smallholder and large producer settings, as well as from developed and developing countries, were discussed.

Moderator: Nicholas Brozovic, Director of Policy, Robert B. Daugherty Water for Food Institute at the University of Nebraska

Richard Bootle, Director, Lawlab and Bogan Farms, Australia

Rod DeBuhr, Water Department Manager, Upper Big Blue Natural Resources District, Nebraska

Wolfgang Kinzelbach, Professor, Institute of Environmental Engineering, ETH Zürich

Steve Walthour, General Manager, North Plains Groundwater Management District, Texas

Slim Zekri, Associate Professor, Sultan Qaboos University, Oman

Wednesday, October 22, 2014

Concurrent Session: Data to Better Understand Climate Systems

Climate plays a key role in many of the water challenges faced by societies around the world. The understanding and effective use of climate information, and the associated climate data, will be paramount to address these challenges, especially in the context of climate change. Panelists addressed

the increasing importance of climate information and climate data for decision-makers in a variety of applications.

Moderators: Donald Wilhite, Professor, Applied Climate Science, School of Natural Resources, UNL, and **Michael Hayes,** Director, National Drought Mitigation Center; Professor, School of Natural Resources, UNL

Peter Gleick, President and Co-Founder, Pacific Institute

Philip Mote, Director, Oregon Climate Change Research Institute; Professor, Earth, Ocean and Atmospheric Sciences, Oregon State University; Director, Oregon Climate Service

Henry Reges, Meteorologist and National Coordinator, Community Collaborative Rain, Hail and Snow Network, Colorado State University

Mark Svoboda, Climatologist, National Drought Mitigation Center, School of Natural Resources, UNL

Concurrent Session: Data from Field to Global Scales

Advancements in digital communication and technology over the last two decades, combined with reduced costs of environmental monitoring sensors, have spurred new ways to capture data about our environment. Numerous and highly complex sources of data are being collected, acquired, transmitted and stored. The panelists illustrated how some of these data are used in agriculture and water resources, providing a wide range of applications from field to global scales. Examples included time-lapse photography, satellite remote sensing and modeling, advanced irrigation sensor networks, state-of-the-art evapotranspiration measuring networks and supporting software and socioeconomic data of smallholder farmers in Africa.

Moderator: Christopher Neale, Director of Research, Robert B. Daugherty Water for Food Institute at the University of Nebraska

Martha Anderson, Research Physical Scientist, Hydrology and Remote Sensing Laboratory, USDA-Agricultural Research Service

Ian Cottingham, Associate Director for Design Studio, Assistant Professor of Practice; Jeffrey S. Raikes School of Computer Science and Management, UNL

Michael Farrell, Special Projects Manager, NET Television; Assistant Professor of Practice, Agricultural Leadership, Education & Communication, UNL

Michael Forsberg, Conservation Photographer, Nebraska; Assistant Professor of Practice, Agricultural Leadership, Education & Communication, UNL

Suat Irmak, Harold W. Eberhard Distinguished Professor, Biological Systems Engineering, UNL

Dave Johnson, Senior Product Manager, LI-COR Biosciences

Stuart Taylor, Director, iQ Performance Measurement, iDE

Closing Panel

Members of the Water for Food Institute's esteemed International Advisory Panel reflected on the critical issues raised, offering suggestions for future actions needed to advance the role of data in ensuring global water and food security.

Moderator: Margaret Catley-Carlson, Vice Chair, Canadian Water Network

Bashir Jama, Director of Soil Health, Alliance for a Green Revolution in Africa

Uma Lele, Independent Scholar and Development Economist, Washington, D.C.

Martin Pasman, President, Valmont Industries de Argentina

Side Events

The 2014 Water for Food Global Conference featured ten side events supporting the conference theme. Convening organizations represented academia, industry, government and non-profit organizations. The events gave presenters and participants an opportunity to engage in discussion, forge partnerships and hear new perspectives related to the conference. To view full presentations, visit **waterforfood.nebraska. edu/wff2014/side-events/.**

Sunday, October 19, 2014

Mitigating Hunger: The Value of Data from a Transdisciplinary and Multi-Institutional Framework

Convening Organizations:
Nebraska College of Technical Agriculture; University of Nebraska at Kearney; University of Wisconsin-Whitewater

Presenters:
Ron Rosati, NCTA
Richard Cummings, UWW
Russell Kashian, UWW
Charles Bicak, UNK
Peter Longo, UNK

Using Data and Innovative Solutions to Deliver on the Water SDGs

Convening Organization:
International Water Management Institute

Presenters:
Peter McCornick, IWMI
Julie van der Bliek, IWMI

Drought Monitoring and Early Warning Systems: Opportunities and Challenges in Harnessing the Data Revolution in the 21st Century

Convening Organizations:
International Center for Biosaline Agriculture; NASA; USAID; National Drought Mitigation Center; UNL

Presenters:
Harvey Perlman, UNL
Michael Hayes, NDMC
Mark Svoboda, NDMC
Shahid Habib, NASA
Rachael McDonnell, ICBA
Giriraj Amarnath, IWMI
Tsegaye Tadesse, NDMC
John Wilson, USAID

Round table discussion at the Utilization of Water in the Food Processing Industry event.

Rachael McDonnell

Utilization of Water in the Food Processing Industry, Are We Doing Enough to Optimize its Usage?

Convening Organization:
UNL Department of Food Science and Technology

Presenter:
Rolando Flores, UNL

The Landesa Model and the Value of Land Rights

Convening Organization:
Prairie Fire Newspaper

Presenters:
Jennifer Duncan, Landesa
Michael Lufkin, Landesa
W. Don Nelson, Prairie Fire Newspaper

Wednesday, October 22, 2014

From Paper to Big Data: Interoperability of Water-Food-Energy Data

Convening Organization: UNL Department of Biological Systems Engineering

Presenter: Francisco Muñoz-Arriola, UNL

Harvesting Data from African Farmers: A Report and Discussion of Three Years of Field-Gathered Data Used to Drive Irrigation Strategies of Smallholder Farmers in Africa

Convening Organization: iDE

Presenters:
Bob Nanes, iDE
Stu Taylor, iDE
Tsegaye Tadesse, UNL

Automating Modern ET Networks with Hardware, Software, and Data Management: China's Nationwide Network of Evapotranspiration Systems

Convening Organization: LI-COR Biosciences

Presenters:
George Burba, LI-COR
Dave Johnson, LI-COR

Irrigation Management Technologies for High Yield Crop Production in Oregon and Washington – A Global Model

Convening Organization:
Lindsay Corporation

Presenter: Fred Ziari, IRZ Consulting

Water Smart Agriculture: The Global Water Initiative's Campaign to Promote and Evaluate Practices and Policies for Improving Water Use in Agriculture

Convening Organization:
Global Water Initiative

Presenter: Paul Hicks, Catholic Relief Services

Juried Poster Competition

The 2014 Water for Food Global Conference featured a juried poster competition for graduate students. Fifty-six posters were entered in six key categories reflecting the major conference themes: Data From Field to Global Scales; Yield Gaps and Water Productivity; Innovations in Data Systems; Data to Better Understand Climate Systems; Water, Food and Health; Economic and Policy Dimensions of Water for Food. Faculty, partners and other professionals submitted an additional fourteen posters. First place award winners are pictured with Roberto Lenton, Founding Executive Director of the Daugherty Water for Food Institute. The Nebraska Corn Board sponsored the competition.

Online Competition

Prior to the conference, twenty-seven students entered an online competition. University of Nebraska faculty served as jurors for the online competition. All winners received cash prizes and free registration to the conference.

First Place ($1,500): Vasudha Sharma, UNL, *Soil Water Dynamics, Evapotranspiration and Single and Basal Crop Coefficients of Cover Crop Mixtures in Seed Maize-Cover Crop Rotation Fields*

Second Place ($1,000): Pamela Pena, UNL, *Modulating Nitrogen Flux in Sorghum and Wheat*

Third Place ($750): Emma Brinley Buckley, UNL, *Communicating Complex Systems to a Public Audience through Time-Lapse Imagery*

Scholarly Competition

All students who presented their work at the conference were entered into the Scholarly Competition. A select group of academic judges at the conference served as jurors for the scholarly competition.

First Place (1,500): Samuel Zipper, University of Wisconsin–Madison, *Spatially Variable Impacts of Shallow Groundwater and Soil Texture on Yield*

Second Place ($1,000): Vasudha Sharma, UNL, *Soil Water Dynamics, Evapotranspiration and Single and Basal Crop Coefficients of Cover Crop Mixtures in Seed Maize-Cover Crop Rotation Fields*

Third Place ($750): Waled Suliman, Washington State University, *Practicality of Biochar Additions for Sustainable Use of Irrigation Water: Influence on Water Retention Characteristics of the Quincy Sandy Soil*

Viewers' Choice Competition

During the poster session, all conference participants had the opportunity to vote for a favorite poster as part of the Viewers' Choice Competition. The prizes for the Viewers' Choice Winner and Honorable Mention were $1,000 and $750 in cash, respectively.

Winner: ($1,000): Emma Brinley Buckley, UNL, *Communicating Complex Systems to a Public Audience through Time-Lapse Imagery*

Honorable Mention ($750): Yulie Meneses, UNL, *Water, the Non-renewable Ingredient for Food Processing*

Vasudha Sharma (right) with Roberto Lenton.

Samuel Zipper (right) with Roberto Lenton.

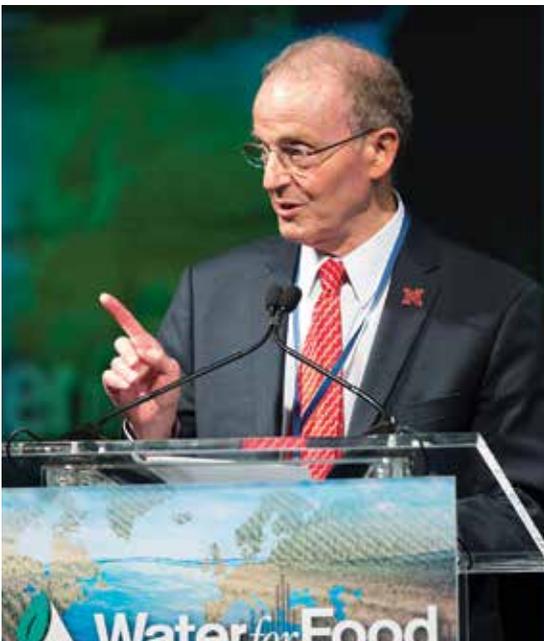*Emma Brinley Buckley (right) with Roberto Lenton.*
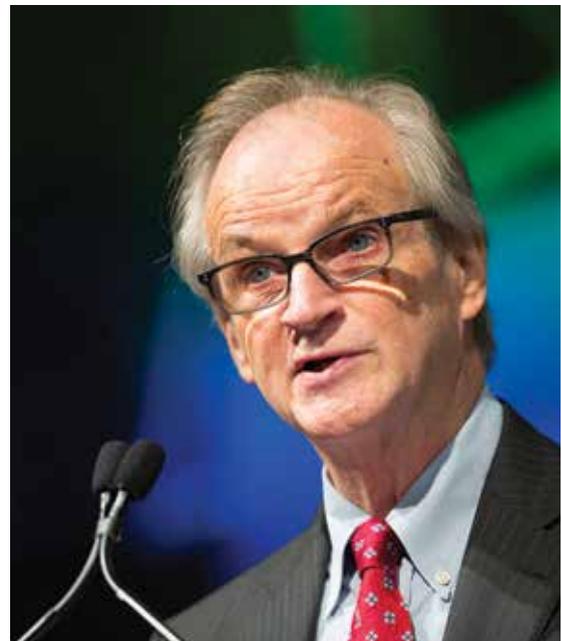
Photos

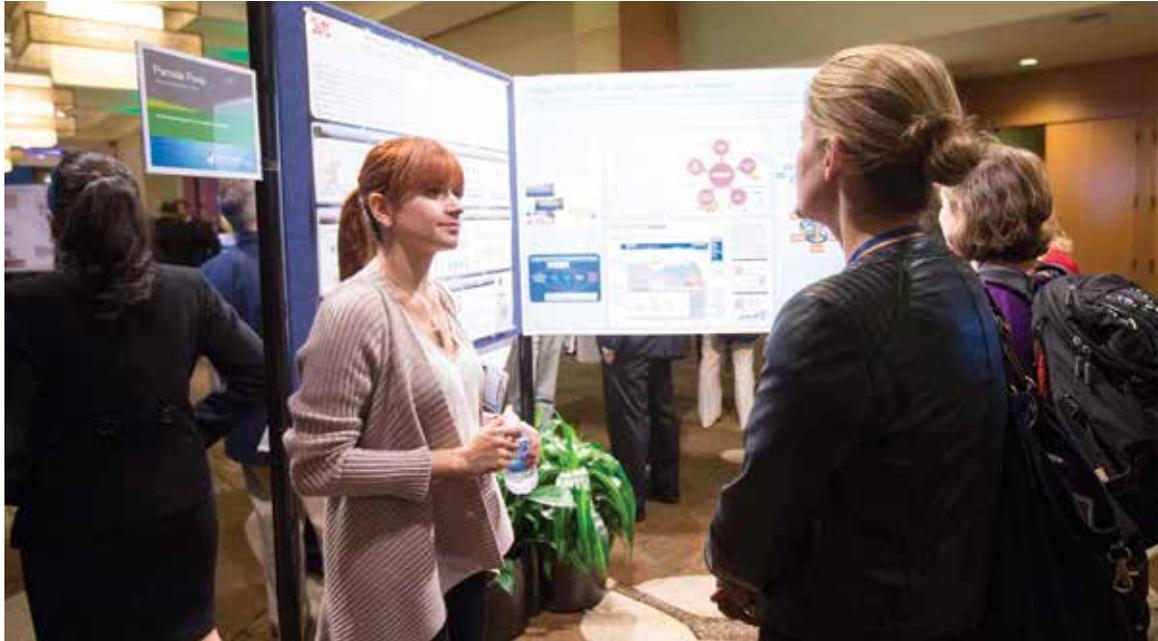*Ali S. Khan, luncheon speaker*

Conference Photos

From left: UNL's Ron Yoder, Judy Diamond and Julia McQuillan socialize with student Yulie Meneses during the Education Share-a-thon.

Harvey Perlman, UNL Chancellor

Roberto Lenton, DWFI Founding Executive Director

UNL student Pamela Pena presents during the poster session.

Participants register at the 2014 Water for Food Global Conference.
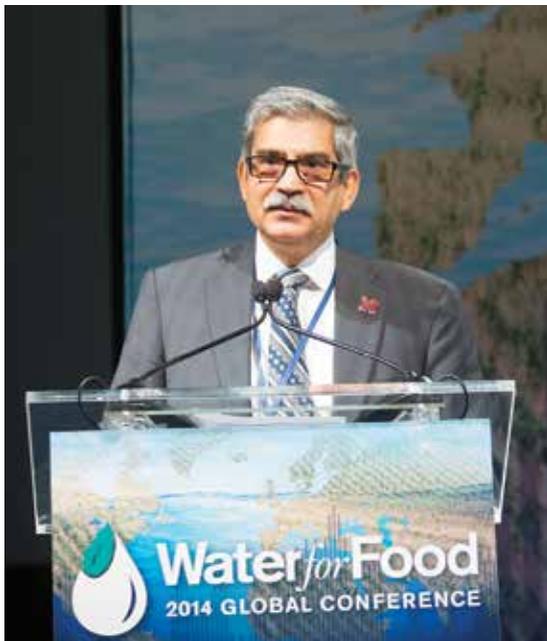
Web producer Steven Speicher describes the multimedia Platte Basin Timelapse project during the Education Share-a-thon.

DWFI and Mammoth Trading's Richael Young presents during the poster session.

Attendees gather in the ballroom.

Prem Paul, UNL Vice Chancellor for Research & Economic Development

Dale Jacobson, World Water Council

Louise Iverson, Chicago Council on Global Affairs

Herman Rosa Chávez, Catholic Relief Services

Roberto Lenton (left) moderated a panel on agricultural development at an event hosted by the Bill & Melinda Gates Foundation at its headquarters in downtown Seattle. Panelists included (from left) Ronnie Green, Ken Cassman, Jeremy Bird and Deborah Barry.

Attendees applaud Mogens Bay (seated left) and James B. Milliken (seated front) during the banquet award presentation.

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