Too **Hot**, Too **Wet**, Too **Dry**

Building Resilient Agroecosystems

Proceedings of the 2013 Water for Food Conference

Lincoln, Nebraska – May 5 - 8

Water for Food
ROBERT B. DAUGHERTY INSTITUTE
University of Nebraska

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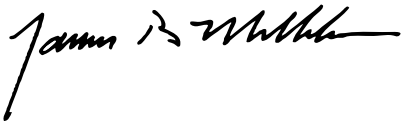
Foreword

During the past few years, climate extremes are having a significant effect on people, crops and livestock in Nebraska and other important food producing regions around the globe. In 2011, an unusually heavy snowpack and an early spring in the Rocky Mountains led to major flooding in Nebraska, followed in 2012 by the worst drought in 50 years. Prolonged droughts in the vast Sahel region of Africa have contributed to severe food shortages in recent years. Drought and floods like these continued to plague important farming regions around the world in 2013.

It is more important than ever to work to mitigate the effects of drought, flood and a changing climate on global water and food security. This was the focus of the 2013 Water for Food Conference, *Too Hot, Too Wet, Too Dry: Building Resilient Agroecosystems,* hosted by the University of Nebraska with major support from the Bill & Melinda Gates Foundation. The conference gave us an opportunity to learn from more than 450 people from 24 countries who shared their ideas about climate, resilience and innovations that will enable agriculture to grow in a hotter and drier world. This report documents the ideas and discussions that emerged from the conference.

The Robert B. Daugherty Water for Food Institute was established in 2010 to focus research, education and policy analysis on the complex problems of ensuring sufficient food and water supplies for current and future generations. Mr. Daugherty, founder of Valmont Industries, the world's most successful irrigation company, knew that research and innovation were the keys to agricultural productivity and feeding our growing world population. And this is one of the driving forces of the Daugherty Water for Food Institute: moving innovative research, technologies and ideas out of the laboratory and into the field through creative partnerships with private and public sector organizations throughout the world.

We hope this report will inform you and encourage you to participate in this critically important global challenge.



James B. Milliken, President
University of Nebraska

Jeff Raikes, CEO
Bill & Melinda Gates Foundation

Preface

It gives me great pleasure to introduce these proceedings of the fifth global Water for Food Conference, *"Too Hot, Too Wet, Too Dry: Building Resilient Agroecosystems."* As in previous years, the 2013 Conference attracted a distinguished array of speakers covering a wide range of subjects. A diverse set of participants from around the world provided for a stimulating exchange of ideas from a variety of perspectives.

The 2013 Conference focused on climate variability and change and what can be done to adapt to climate extremes and changing conditions. From the keynote speeches on the impacts of climate change to the discussions of resilience and coping with hotter and drier agriculture, the message was clear: climate change is real and the scientific evidence is compelling. We urgently need to find better ways of mitigating and adapting to floods, droughts and the effects of climate extremes.

The speakers also brought good news. An array of technologies and practices are available to help farmers improve yields and conserve water resources. Better methodologies help planners and decision-makers anticipate and prepare for climate extremes. And these extremes provide opportunities for public education, for learning and forging new research partnerships, and for action.

The conference also provided a forum for discussing related issues. One of these was livestock and water, a critically important relationship that is poorly understood and often ignored in discussions of water and agriculture. Two sessions, one a panel of scientists working in the area of livestock and water and the second a panel of ranchers, illuminated the complex relationship between livestock production and water in different contexts around the world. These discussions exemplified how the Water for Food Institute can stimulate global policy debates on subjects that are critical to ensuring water and food security at local and global scales.

This conference was the last to be organized by Monica Norby, Associate Director of the Institute at that time and now Assistant Vice-Chancellor for Research at the University of Nebraska-Lincoln. I would like to thank Monica for her leadership and skill in organizing this conference and the four that preceded it. I also want to express my appreciation to our staff and University collaborators who worked tirelessly to ensure the success of the conference. Last but not least, I would also like to thank the Robert B. Daugherty Foundation, the Bill & Melinda 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

One

Neal Palmer, CIAT, Flickr

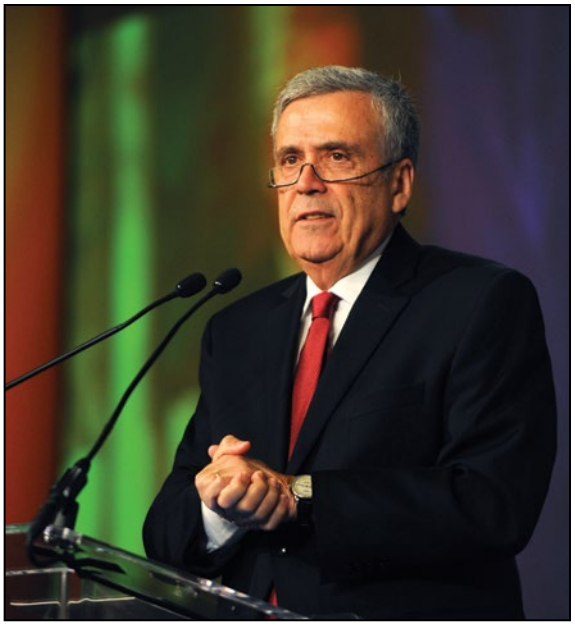
Water for Food Introduction

Despite impressive food productivity advances achieved in the past, the world's population, expected to reach 9 billion by 2050, will demand even more from the scientific and political communities, said Benedito Braga, president of the World Water Council. "Good agricultural practices are not the norm worldwide," he said.

As keynote speaker at the 2013 Water for Food Conference, Braga laid the foundation for the presentations and discussions to follow. Water security, he said, is a key element to ensure human and basic needs. But the risk of failing to meet these needs continues to grow as demand expands and supplies shrink. The threats to water security are many, including increasingly competitive uses, ongoing environmental degradation and greater climate variability and change. More than 1.2 billion people already live in river basins where water scarcity is normal.

Water embraces politics, health, economics, food, energy, the environment and many other sectors and acts as an overarching link between them, Braga said. In many countries, for example, economic growth is dependent on rainfall: little economic development takes place when rainfall is low. To grow and prosper in the future will require the capacity to manage the uncertainties of too little or too much water. Infrastructure, therefore, becomes even more necessary, particularly in developing countries. For example, from 1997 to 2000, floods and droughts cost Kenya the equivalent of about 22 percent of its Gross Domestic Product, a number large enough to justify building dams, canals and other water infrastructure, he said.

The world food crisis reached unprecedented levels in 2007 and 2008, and hunger riots broke



Benedito Braga

out in 37 countries, revealing that food supplies cannot meet global demand. "Structural, and not only cyclical, reasons explain this crisis," Braga said. "These hunger riots could be harbingers of crises to come."

"Without a rapid change in direction, our planet could become a passive victim, bringing with it high costs and major risks. It is in our hands to show to the world that we can produce more food with higher quality and with less wastage."

At this year's conference, presentations and discussions centered around several topics implicit in Braga's directive:

- Climate change is a reality, and immediate steps must be taken to mitigate its effects. Rosina Bierbaum, professor of natural resources and the environment at the University of Michigan, made a powerful case for the human causes and consequences of climate change. Heidi Cullen,

Water for Food Introduction

chief climatologist at Climate Central, described the challenges of engaging society to enact the changes necessary to cope with and mitigate the effects of climate change. She also moderated a roundtable on communicating climate change. Cynthia Rosenzweig, of the National Atmospheric and Science Administration's Goddard Institute for Space Studies, described one project the agricultural community has undertaken to address climate change.

"It is in our hands to show to the world that we can produce more food with higher quality and with less wastage."

Ben Braga

- As awareness of climate change and other global environmental challenges has grown, the concept of resiliency has emerged as an important research area, particularly in understanding how to sustain global and local food production. Christo Fabricius of Nelson Mandela Metropolitan University in South Africa explained resilience, its role in social and ecological system regime shifts and why the concept is relevant to meeting global food production demands. Panelists from around the world described how this concept informs their research during the "Resilience in Working Agricultural Landscapes" session.

- With the U.S. Midwest still suffering from the extreme drought of 2012, increasing farmers' resilience to drought and mitigating its effect on food insecurity worldwide were prominent topics. Ronnie Green, vice chancellor of the Institute of Agriculture and Natural Resources at the University of Nebraska-Lincoln moderated "Surviving the 2012 Drought: 80 Years of Innovation," a panel of researchers and industry representatives who discussed how agronomic practices and technology have improved farmers' ability to withstand drought. UNL plant scientist Sally Mackenzie explained how her research investigating epigenetics may one day improve stress tolerance and yields. Support services are also vital to helping farmers and communities. Dean of UNL Extension Charles Hibberd described how U.S. extension services help farmers and ranchers plan for and weather drought, while the "Drought Preparedness Case Studies" panel explored broader, international efforts to help farmers and communities suffering from droughts and drought-caused famines.

- While farmers are at the center of food production and global food security, they are frequently left out of research and policy decision processes. As it does each year, the conference featured "A View from the Field – Agricultural Producers Panel" with ranchers from Brazil, Nebraska and Colorado as well as a Nebraska farmer and cattle feeder. Each described his views on livestock production and ranching's role in society and the environment. Charles Hibberd, dean of UNL Extension, described how extension services throughout the U.S. support producers and communities and take research to the field. This year also included the view from participatory researchers, who engage farmers, policymakers and other local stakeholders. This compelling panel, "Research in Action," was moderated by Jeff Raikes, CEO of the Bill & Melinda Gates Foundation.

- Calls to reduce meat consumption as a method of blunting food production's demands on water and other natural resources have been growing. Panelists in the "Livestock and Water: Global Perspectives" session agreed that significant advances in production efficiency have reduced those demands and more gains are possible. They described their research into understanding and improving livestock production on global and local scales. In "A View from the Field – Agricultural Producers Panel," two producers described why ranchers are important stewards of the land and how their operations help conserve the environment.

- New technologies are expanding data collection into remote and difficult locations. Better access to more accurate and timely information allows researchers, farmers and resource managers to make better decisions, which improves yields and conserves resources. Researchers at the University of Nebraska-Lincoln are developing "Cool Tools & Technologies for Water and Agricultural Research" that collect information in new ways, then send it wirelessly, analyze it and put it into user-friendly formats that encourage adoption.

Curious cows and calves

Two

Nikki McLeod, Flickr

Resilience in Agroecosystems

Ecosystems are normally resilient, able to bounce back from natural disturbances. But human actions are triggering environmental tipping points and irreversibly changing ecosystems, which threatens food security, water resources and social well-being on local and global scales.

Craig Allen

Climate change is perhaps the most familiar example. Scientists have long warned that the atmosphere is quickly approaching a carbon dioxide load beyond which the planet cannot recover.

Panelist Craig Allen, UNL wildlife ecologist, described the numerous critical services ecosystems provide society, from nutrient cycling to water purification. But unprecedented global changes, including climate change, the conversion of more land to agriculture and increasing water storage, are degrading many ecological services.

"It may be too late," Allen said. "We may have crossed tipping points already, and it's just that those tipping points haven't manifested for us yet."

Resiliency, Tipping Points and Regime Shifts

As awareness of these global environmental changes has increased, the concept of resiliency has emerged as an important research area, particularly in understanding how to sustain global and local food production.

Resiliency is a socio-ecological system's capacity to absorb disturbance and to reorganize so as to retain essentially the same function, structure and feedbacks, said Christo Fabricius of Nelson Mandela Metropolitan University, South Africa, during his plenary presentation. Systems aren't static, but fluctuate around a normal range of resiliency. Overshoot that range, however, and the system passes a threshold beyond which it falls into another domain, or identity. Once the underlying structure and function changes, the system has undergone a permanent regime shift.

"Most of the losses in resilience are due to unintended consequences of processes that are outside the focal scale," said Fabricius. "While managers are looking down to the ground, there are other things happening off their radar screen, which are driving the system along." The system can cope to a point, but once it reaches the threshold, it changes suddenly and irreversibly.

Christo Fabricius

Resilience in Agroecosystems

In one South African community, for example, policies and social behavior have created a complex set of feedbacks that is shifting the traditional mosaic of grasslands and woodlands to primarily woodlands, slowly eliminating the people's ability to graze cattle. Reasons range from a no-burning policy to requiring children, who traditionally tend herds, to go to school, which reduced herd sizes. Both policies, among other changes, allowed woodlands to prosper.

> *"We may have crossed tipping points already, and it's just that those tipping points haven't manifested for us yet."*
>
> *Craig Allen*

Fabricius described another system in which a succession of changes culminated in driving farmers from the system entirely. These changes included increasing global demand for dairy products, a drought, over-pumping of groundwater and, finally, subsidized cheese from abroad.

"Trying to learn and understand how these successions of global factors, local responses and adaptions, many of them unintended, result in a slow slide of the system from one state to the next… we believe could be key to understanding the sustainability of our food systems," Fabricius said.

Agroecosystem Resiliency

The world's food systems operate within a safe zone. But as meat and fuel consumption increase and as water and soils degrade, the planet is probing the boundaries of this zone to the point that sudden, nonlinear change is flipping systems into a completely different domain.

Food self-sufficiency in poor countries is a key variable in a resilient global food system, and the future doesn't look promising, Fabricius said. While global per capita food production has increased since the 1960s, it's declined in many parts of Africa. A Global Harvest Initiative report predicts that only 13 percent of Sub-Saharan Africa will be food self-sufficient by 2030. "What does this hold for the resilience of our planet?" he asked. Other foreboding global indicators include the high percentage of income spent on food in poor countries and the unknown consequences of biofuel production's rapid rise.

Regime shifts also threaten local agroecosystems. Panelist Line Gordon, of the Stockholm Resilience Center, described research in Tanzania where a productive state that supported smallholder farmers in the 1950s has degraded, resulting in frequent crop failures due to population growth, increasing dry spells and a breakdown of once successful management institutions. When crops fail, some food is purchased, but some comes from livestock and foraging.

"One of our main conclusions is that the surrounding landscape is a very important insurance mechanism when crops are failing," Gordon said.

Line Gordon

Alex Awiti

"So if we're trying to build resilience of these farmers, we also need to understand how this larger landscape contributes to resilience, so we don't change the landscape in a way that can't support this insurance mechanism unless it's definitely not needed anymore."

Her research illustrates the trade-offs involved in managing agroecosystems. Converting wild landscapes to agriculture enhances food production, for example, but the consequences can be significant, including reducing water downstream, altering the hydrological cycle and changing cultural values, Gordon said.

Panelist Alex Awiti, of Aga Khan University in Kenya, investigates soil regime shifts following forest conversion to agriculture in the Guineo-Congolian Forest in western Kenya. Using indices, such as spectral reflection, soil organic carbon and water retention, Awiti and his colleagues found that soil degraded significantly over time.

The consequences go beyond reduced crop yields, he said. Greater water runoff from reduced soil water infiltration, coupled with overgrazing, dump sediments into Lake Victoria, changing the lake's ecological structure and undermining a vital fishing industry.

The degradation of Lake Victoria, which supports up to 3 million people, demonstrates the threat to an important source of global food that receives little attention, added panelist Doug Beard, chief of the U.S. Geological Survey's National Climate Change and Wildlife Science Center. Inland fisheries provide 60 million jobs globally, particularly for women, and are a culturally significant source of energy-dense food for millions.

Resilient aquatic ecosystems are necessary to maintain inland fisheries, Beard said. He emphasized the trade-offs inherent in managing systems that affect aquatic resources. Hydropower, for example, is seen as an opportunity in many areas, but has huge implications for fish production. Irrigation schemes in the Mekong Basin, for example, are estimated to cost a million tons of fish.

Lake Victoria

"My view of resilient food systems is they need to be integrated," he said. "Food needs to come from a variety of sources, and we need to recognize that when we make a decision on moving water from one place to another, it's going to impact something. We may get more food of one sort, but we're probably having an impact on food of some other sort."

Resilience in Agroecosystems

Resilience versus Transformation

Panelists described efforts to promote resiliency within agroecosystems. In the Kenyan rainforest, for example, resiliency requires establishing an allowable range for soil health within which farmers can manage. But costs, negotiating with farmers and engaging policymakers are challenges, Awiti said. "This demonstrates that these systems can actually recover, but it's also easy to maintain them in this very low production system, and they can be very resilient to this suboptimal state."

Marty Anderies, of Arizona State University, described a resilient Nepalese village agroecosystem. The community has used collective action to manage irrigation for thousands of years, and he asked whether they could continue to successfully adapt to changing climae and socio-economic conditions. "We believe that the adaptive capacity of small-scale socio-economic systems is fundamentally important for food security at the global scale," he said.

Adaptive institutions that change the rules as they go vastly improve the system's robustness, Anderies said. But they're tied to the local context, which makes them fragile to changes. Collective action works effectively in a stable environment, but uncertainty undermines the trust required.

> *"Most of the losses in resilience are due to unintended consequences of processes that are outside the focal scale."*
>
> *Christo Fabricius*

Adaptive communities are resilient and can easily deal with climate change induced weather shifts, he added. But adjusting to both climate change and socio-economic shifts, such as increasing uncertainty or outmigration, may cause cooperative capacity to collapse.

Doug Beard

Adaptability is important in maintaining resiliency, but sometimes a system is undesirable, Fabricius said. Transformability—how prepared a system is to change—then becomes an important characteristic. Systems that successfully transform do so by building social capital and trust, forming networks and waiting for a window of opportunity, which may be a policy shift or change in personnel. Then, by working together and learning through experimentation, the system crosses the threshold and builds resilience in a new direction.

A system's transformability relies on its capacity for decision-making, he emphasized. Decision-makers must be committed to making the system

work, to partnering with the private sector, economists, agriculturalists, and others, and to investing in research and extension services.

Knowing when to build resilience and when to build transformative capacity is the "holy grail," Fabricius said, joining the panel to take questions. Australian peanut farmers should change, for example, because the climate is no longer suited to peanut farming. But their identity is strongly tied to the land, which makes them resilient and unwilling to transform. "That realization of the need to transform has to come from within, and it's a long process," he said.

UNL's Allen suggested looking to Florida's mullet fishery as a successful model of transformation. The government began regulating mullet, while also putting effort into a clam industry. Today, people are proud of the successful clam industry.

Understanding successful transformations from undesirable states is necessary to improve future food production, Fabricius said.

He also provided steps to promote resilience during his plenary presentation, including maintaining diversity and redundancy in farming; managing connectivity between social networks and in the ecosystem, such as preventing landscape fragmentation; and promoting decision-making at multiple levels. "In the end, if we look at the social aspects of resilience, collaboration, trust building and networking lie at the heart of it," Fabricius said.

From left: Marty Anderies, Christo Fabricius, Doug Beard, Line Gordon, Alex Awiti and Craig Allen

Three

Chris Goldberg, Flickr

Climate Change: Insights, Impacts and Communication

As atmospheric carbon dioxide levels approached the record 400 parts per million milestone in May 2013, climate change was a major topic throughout the conference and experts described its effects on agriculture and society. Climate change is a reality, they agreed, and society must take immediate steps to lessen the impacts already being felt and to mitigate future severity.

The Reality

The scientific consensus is clear: human activity is causing climate change, said Rosina Bierbaum, professor of natural resources and environment at the University of Michigan and a member of the President's Council of Advisors on Science and Technology. While some greenhouse gases occur naturally, atmospheric carbon dioxide has increased 40 percent since 1880 and is already much higher than its historic cyclic highs going back 650,000 years, she said. The temperature, which is strongly correlated with carbon dioxide levels, has risen 0.8 degrees Celsius since 1980 and continues to go up.

Even that relatively modest temperature increase has caused significant global changes, including rising sea levels, increased water vapor and loss of ice, Bierbaum said. Ice loss, in fact, is happening much faster than expected.

Rosina Bierbaum

During the 2012 summer season, the entire Greenland ice sheet was melting for the first time. As the reflective surface of ice disappears around the globe, more solar heat is absorbed, leading to even faster warming. Many fear this nonlinear change is leading to a tipping point in which the ice will disappear and never return. Greenland ice holds 21 feet (6.4 meters) of sea level rise.

> *"We've seen food crises in many parts of the world in recent years, which helps show how fragile our food distribution systems are and how we are going to have to attend to that going forward."*
>
> *Rosina Bierbaum*

When the planet reaches a 2 degrees Celsius temperature increase, 30 percent of the world's species will be endangered and extreme weather will stress a billion humans, including loss of tropical glaciers, an important water source for many major cities.

Despite such persuasive evidence of global-scale degradation, the world's primary energy sources remain largely carbon based, and each year burning carbon-based fuels adds 9 billion tons of carbon to the atmosphere, Bierbaum said. Energy use is expected to triple by 2100.

Global changes already affect global food production, she said. Spring comes earlier, crops are shifting northward and pests are surviving milder winters. More critically, extreme heat events are 20 to 100 times more prevalent than 30 years ago and droughts are increasing, causing famines and more than $5 billion in annual crop losses.

Climate Change: Insights, Impacts and Communication

From left, Heidi Cullen addresses panelists Gregg Garfin, Mark Svoboda and Doyle Rice

The U.S. Midwest agricultural zone is experiencing some of the largest anomalies. In 2012, temperatures were 4- to 6- degrees higher than normal and an extreme drought was widespread and prolonged.

Droughts drive up food costs, affecting food and water security globally. Climate change could result in grain crop production losses exceeding 50 percent, primarily in countries already subject to famine and drought, Bierbaum said.

"We've seen food crises in many parts of the world in recent years, which helps show how fragile our food distribution systems are and how we are going to have to attend to that going forward," she said.

Communicating Risk

While Bierbaum made a powerful case for the human causes and consequences of climate change, Climate Central's chief climatologist Heidi Cullen described the challenges of engaging society to enact the changes necessary to cope with and mitigate its effects.

Scientists have done a poor job of communicating the science of climate change and its urgency, she said. Only 16 percent of Americans surveyed say they are alarmed about climate change, while nearly twice that many range from disengaged to dismissive. About half are concerned or cautious.

Humans process immediate threats through the brain's amygdala, which sends us into fight or flight. But climate change and droughts are long-term, data-driven threats to which humans aren't hard-wired to respond. How do we convince ourselves that this is urgent enough to take action? Cullen asked.

Hurricane Sandy, which struck the northeastern U.S. in 2013, and other extreme events provide opportunities for talking about climate change.

To further explore those issues, Cullen also moderated a panel on communicating climate change with USA Today weather reporter Doyle Rice, the National Drought Mitigation Center's Mark Svoboda and Gregg Garfin, of the University of Arizona. Each panelist communicates about climate change in different forums and to different audiences, but each described the importance of trust and persistence.

Journalist Rice said readers particularly want to know if natural disasters are related to climate change, but making that linkage isn't always helpful. Climate change effects often are subtle and happen in slow motion, so communicating those indistinct complexities is challenging. "We have to keep hitting on the science," he said.

For that, he often turns to Svoboda, who said he gives about 200 interviews a year, and many more during bad droughts, because sharing the information helps people make decisions. But he acknowledged the challenges.

"It is difficult to explain to people, of all levels, the idea of risk and probabilities and uncertainty," Svoboda said. "So one of our jobs in translating science into information is to hopefully bridge that gap and talk to them in terms that they can understand."

Mark Svoboda

Drought is part of the climate cycle, he added, and another part of his job is to get policymakers to proactively plan for drought. Both he and Garfin emphasized the need to build relationships in helping decision-makers adjust to and prepare for climate change.

"The greatest tools that we have are not necessarily the knowledge that we have, but conversations and discussions with decision-makers," Garfin said. Building relationships is the precursor to establishing trust, and it requires letting people know you're looking for a relationship, then finding common ground.

> *"We have to keep hitting on the science."*
> *Doyle Rice*

Asked how to deal with the gap between what is known and what decision-makers want to know when building trust, Garfin said open dialogue and understanding decision-makers' constraints are critical. Establish expectations early on, he advised, and if the information is unknown, engage in a long-term relationship to track knowledge over time.

Mitigating and Adapting

It's not enough to understand and accept climate change; action to both mitigate future changes and adapt to those already occurring is urgently needed, Bierbaum and Cullen agreed.

"In order to do this, we would absolutely globally have to fundamentally transform our energy system," Bierbaum said, including using energy

Climate Change: Insights, Impacts and Communication

more efficiently, incorporating renewable sources and sequestering captured carbon. It's clear the globe is heading toward devastating ecological and societal changes, but countries have yet to even commit to making the changes necessary to alter the trajectory.

> *"The greatest tools that we have are not necessarily the knowledge that we have, but conversations and discussions with decision-makers."*
>
> *Gregg Garfin*

Too little is being done to adapt to changes already underway as well, both Bierbaum and Cullen said, including infrastructure to withstand new extremes, emergency response plans, prioritizing land preservation, improved weather and climate monitoring, and developing social safety nets.

It's a question of values, Cullen said, such as continuing to build homes in coastal storm surge zones. "We want to be able to build resilience into the long term."

Cynthia Rosenzweig, of the National Atmospheric and Science Administration's Goddard Institute for Space Studies, described one project aimed at improving agriculture's capacity to adapt to climate change. Begun in 2010, the Agricultural Model Intercomparison and Improvement Project, or AgMIP, is an international effort linking climate, crop and economic modelers with information technology to improve models and climate impact projections for the agricultural sector.

"This global work is designed to help [international treaty] negotiators know what climate change means for their countries, so they can make informed decisions in the global process, as well as then, in their own countries, see the longer term context for their regions," Rosenzweig said.

Modeling research is now mature enough for scientists to come together, share routines and compare results, she added. AgMIP currently consists of more than 500 modelers from around the world.

Tremendous research has gone into making climate models robust. "But that work has not been done on our crop models and on our economic models," Rosenzweig said, adding that the agricultural community must now put similar effort into its modeling, so the impacts of climate change are as well understood as climate projections.

Cynthia Rosenzweig

From left, Heidi Cullen, Gregg Garfin, Mark Svoboda and Doyle Rice

She described some of the projected impacts to date, including rising agricultural prices and, in many regions, limitations in fresh water availability for irrigation that may aggravate climate effects.

To further explore the impacts of water supply and demand on agriculture, AgMIP is bringing together expertise in relevant fields to improve integrated assessment studies. "What we're really doing in AgMIP is building capacity worldwide," she said.

Global catastrophes are increasing and preparing for climate change is urgently needed across all societal sectors, the speakers agreed. By 2060, the summer heat wave in Europe that killed 35,000 in 2003 will seem cool, Bierbaum said, adding that "unselfish" solutions must be enacted fast before it's too late to reverse the damage.

Four

Hotter and Drier Agriculture

For many farmers, drought is a regular occurrence. But climate change is increasing drought prevalence and severity worldwide, straining farmers' resilience to drought and increasing the likelihood of greater food and water insecurities in the future.

Many in the agricultural sector are working to better equip farmers to withstand drought and to build resilience into the agricultural system. Technological advances, improved agronomic practices and growing support networks at both national and international levels have already made much progress, but more is needed.

In 2012, the U.S. agricultural heartland and much of the western U.S. experienced a long and extreme drought— including the driest year in Nebraska's history. While its effects devastated many crops, others did well, demonstrating how far technology, agronomics and support systems have advanced, said Ronnie Green, University of Nebraska vice president and University of Nebraska-Lincoln vice chancellor of agriculture and natural resources. Green moderated a panel on surviving the 2012 drought.

Irrigation

Despite the extreme drought of 2012, Nebraska's overall yields were high thanks to the state's extensive use of irrigation, Green said. Dryland corn farmers, for example, experienced a 57 percent reduction in yields, while irrigated farms increased yields by nearly 6 percent.

"So a powerful impact of irrigation, certainly, that we experienced here in this part of the Corn Belt compared to our neighbors," Green said. But those yields came at a cost: groundwater levels

Ronnie Green

dropped more than 5 inches (13 centimeters) in places, a two-fold increase over the previous record.

Center pivot irrigation systems, prolific in Nebraska, were first introduced in the 1950s and have evolved over the years to reflect changing conditions and growing awareness of water conservation, said Jake LaRue, of Valley Irrigation. Improvements include the ability to control droplet size and reducing evaporation by lowering sprinklers closer to crops.

More recently, tying precision management tools, such as soil moisture sensors and rain gauges, into the center pivot software is helping farmers make irrigation decisions. The industry continues to move toward greater precision applications.

Water is the biggest limiting factor to farmers' yields, and the 2012 drought demonstrated the center pivot's important role in managing drought risk. "One of the things that we have tried to do

Hotter and Drier Agriculture

with the center pivots is really to integrate them into a total production system," LaRue said.

Panelists from left: Jake LaRue, Nick Emanuel and Robert Klein

Panelist Nick Emanuel, founder of precision agricultural solutions company CropMetrics, said fine-tuning irrigation applications requires an in-depth understanding of each field's soil and topography. He described his company's process to understand field variabilities. That information can then be used to precisely apply water by adjusting the center pivot's speed and individual nozzle water release.

Accounting for additional variables, such as hybrid differences and tillage practices, will mean even greater precision and yields, Emanuel said. "When we look at precision water management and integrating some of these technologies, it's really looking at the complete systems approach and integrating these technologies with your other management practices," he said.

Not all water improvements are necessarily high-tech. Longtime UNL agronomist and farmer Robert Klein described one practice that continues to make a significant difference. Conservation tillage, which leaves crop residue on the field, reduces evaporation and saves up to 1.5 inches (3.8 centimeters) of water.

Klein showed dramatic examples of increased soil moisture and subsequent yield improvements attained solely from leaving residue versus tilling. "Farmers that do this kind of thing, strip-till or so forth, especially in our dryland, are wasting some real valuable moisture," he said.

Technology

Technological improvements go well beyond irrigation, Green said. Yield gains during the 20th century demonstrate the impact of improving hybrids, biotechnology and pest management. Corn yields, for example, have increased from 28 bushels per acre (1.9 tons/hectare) in 1900 to nearly 150 bushels per acre (10.1 tons/hectare) in 2010

Panelist Jim Specht, a UNL agronomist, described the science behind increasing yields in corn and soybeans, while also improving water use efficiency. For each carbon dioxide molecule that passes through a plant's open stomatal pore, 400 water molecules escape. The research goal, he said, is to increase the crop per drop.

Jim Specht

Yield is dependent on the amount of water flushed through the plant during transpiration and the amount of carbon captured. The more water plants use, the more yield is attained, so water that escapes through evaporation is wasted and reduces water use efficiency, Specht said.

Marta Garcia

Biotechnology has played a significant role in improving crop yields, according to two representatives from agricultural biotechnology companies.

"The adoption of biotechnology has been amazing," said Marta Garcia of Dow AgroSciences. "It's been significant as one of the technologies that's had greater or faster adoption than [others]." She cited the adoption of biotechnology products in developing countries, such as Argentina, South Africa and India.

However, biotechnology is one tool of many, she emphasized. Improving yields is a complex issue that requires multiple solutions. She described the evolution of Dow seed products designed to increase insect resistance that evolved from using a single mode of action to multiple modes acting in concert.

Though devastating to many, the 2012 drought was the opportunity to improve products designed to withstand drought, said Joe Keashall, of DuPont Pioneer. He described the company's drought resistant Optimum® AQUAmax product.

"We're in it for the long run, and we're willing to take some of the expensive, high-risk, high-reward endeavors," Keashall said, when asked about the tremendous investment required to make incremental advances in yields. Products developed for a Western market will also be available to developing countries once the infrastructure is in place, he added.

Introducing genes with favorable traits isn't the only way to use biotechnology to improve crops. How genes are expressed, called plant epigenetics, may also one day improve stress tolerance and yields, said UNL plant scientist Sally Mackenzie during her plenary presentation.

Plants that experience stress pass on a coping adaption to their progeny. Mackenzie described her research into a promising gene associated with high stress tolerance. By turning the gene off and crossing the modified plant with a wild type, she can alter subsequent generations' epigenetic configurations, taking advantage of their increased stress tolerance and yield improvements.

Joe Keashall

Hotter and Drier Agriculture

"If we can capture this, exploit this, we might actually have the opportunity to enhance our breeding capabilities beyond where we are now," Mackenzie said.

Sally Mackenzie

Support Networks

Technology isn't the only tool needed to help farmers survive drought. Support systems play an increasingly critical role, locally and globally.

Extension services, available through U.S. land-grant universities, encourage and help producers and communities prepare for drought, said Charles Hibberd, dean of UNL Cooperative Extension Division, during his plenary presentation.

Monitoring is a key component to those preparations, and Hibberd said the U.S. is fortunate to have the National Drought Mitigation Center, housed at UNL. The center's real-time data gathering, analyses and extensive tools help extension agents, producers and others nationwide understand what's happening and to plan appropriately.

UNL agronomist Jerry Volesky said during the "Livestock and Water" panel that drought can be especially damaging to ranchers because it can degrade grasslands for years by changing plant physiology and the overall plant community composition. So managing herds to maintain grassland vigor and resiliency during drought is particularly critical. Extension educators play a critical role in working with ranchers to develop drought plans for grazing and storage, hay production and stocking rates, which lessen drought's impact and reduce ranchers' stress.

The 2012 drought inevitably led to overgrazing, he added, but as drought became evident, good managers culled herds more intensely and weaned calves early, among other strategies.

Ana Iglesias, of the Polytechnic University of Madrid, said she is impressed by the services available to U.S. farmers and that such services are greatly needed in the arid regions in which she works. She described a multi-institutional, multi-national project to generate ideas for coping with water scarcity and drought in Africa. The DEWFORA project is developing protocols to use science to implement appropriate drought management actions.

The major goal is dealing with hazard and social vulnerability, she said, adding that the social component is just as important as the physical. "We recognize that there are very large disparities

Ana Iglesias

between water users," she said. "We want to especially understand how drought brings disparities and [how] we can reach the most vulnerable populations."

Mohamed Bazza, of the United Nations Food and Agricultural Organization, said the FAO began specifically targeting drought in the 1990s. He described the pilot projects, data and reporting efforts, training programs and other activities the FAO has conducted since that time.

Drought preparedness and risk management are solutions to surviving drought, he said. Planning must be decentralized, with full stakeholder participation and institutional collaboration. The FAO also seeks partnerships and has partnered with many international and local groups, including the Daugherty Water For Food Institute.

Mohamed Bazza

"All in all, it's really about integration and partnerships, because there's not one single institute or organization that can address the issue of drought," Bazza said. "And I think collaboration is the basis for that, otherwise I think we are doomed to failure."

Gary Eilerts, of the Famine Early Warning Systems Network, agreed. FEWS NET, a division of the

Gary Eilerts

U.S. Agency for International Development, works closely with the FAO, nations and others to carry out its mandate to ease food insecurity in 35 countries.

He described FEWS NET's attempts to become an early warning system for famine and used the 2011 famine in Somalia to demonstrate the complexity of predicting famine and providing timely relief. Terrorism and drought are two examples of the challenges, but another is that expectations can contradict local conditions. "Sometimes global models don't reflect local realities," he said. "In those areas where you're going to change something, you need to know exactly what's happening."

Conclusion

Despite advances, the agricultural sector needs to continue evolving, Green said. "And we need to do it rapidly and smartly in order to meet those challenges that are ahead." The 2012 U.S. drought will continue to affect producers in coming years, he added. Cattle numbers are at their lowest point since 1952, hay stocks are the lowest ever recorded and winter wheat crops will suffer from lack of soil moisture. Droughts worldwide will only become more severe, and more must be done to prepare for them.

Five

Rita Willaert, Flickr

Global Perspectives on Livestock and Water

Demand for meat and dairy products continues to grow worldwide, raising concerns about the livestock industry's environmental impact. But significant advances in production efficiency have blunted those effects and more gains are possible, agreed panelists in the "Livestock and Water" session.

The global livestock industry is under threat, said livestock sustainability consultant Jude Capper. "The consumer is bombarded with these images that say, 'You care about the planet, you shouldn't eat meat,'" she said. Activist groups use faulty data and consumer-friendly metrics (one steak equals 50 baths is one example) to push vegetarianism and veganism. Mainstream media are also guilty, she added, citing a National Geographic article that she said used faulty data from the Water Footprint Network. Exposure to incorrect information misleads consumers and may bias food choices.

Despite these messages, meat and dairy consumption is increasing globally, driven by growing populations that are more urban and affluent, said Mats Lannerstad, of the International Livestock Research Institute and the Stockholm Environment Institute. Consumption patterns are also shifting. Until about 1980, consumers preferred beef. Now pork is the top seller, and poultry is projected to replace pork by 2020.

Production systems also have changed, shifting from primarily land-based operations to concentrated, industrialized systems—an unsustainable situation, Lannerstad said. Globally, however, systems are highly dichotomous: primarily high-tech and large scale with low biodiversity in the U.S. and other developed countries, and low-tech and small scale with high biodiversity in developing countries.

Panelists agreed that while increasing efficiency has produced the same amount of product with fewer animals, thereby lessening the industry's environmental impact, environmental concerns — water consumption, natural resource degradation and greenhouse gas emissions — are real, and growing demand will require additional advances.

Jude Capper

"If we are to meet these increased demands without further environmental pressure, and specifically without higher water consumption, you'll need to make some gains in livestock water productivity," said Katrien Descheemaeker of Wageningen University in The Netherlands.

Global Perspectives on Livestock and Water

Livestock and Water

While nearly all water consumed in livestock production comes from crops grown for feed, research presented during the session demonstrates the complexity and variety of global livestock production that make generalizations harmful.

In some systems, for example, poultry production is more resource intensive than beef, which often draws more criticism, Lannerstad said. Pigs and poultry, the monogastrics, are primarily grain fed and raised in industrial systems. Cattle and other ruminate production primarily uses a mixed system of rangeland grazing and industrial grain. The difference in reliance on crops for feed translates globally into 1.5 times greater water efficiency in raising cattle than monogastrics.

Descheemaeker said livestock water productivity is a useful concept to help identify entry points for improving livestock productivity and reducing its environmental burden. Calculated by water flows on one hand and livestock products and services on the other, livestock water productivity links those two building blocks with feed, which depletes water, and the physiological energy that feed provides to drive production. Various factors influence these linkages, such as crop management, feed quality and herd composition.

Adjusting those factors by understanding local water productivity conditions allows ranchers and policymakers to improve livestock efficiency and livelihoods, Descheemaeker said. Her research in the Ethiopian highlands, for example, determined that half of livestock water use was lost as unproductive water flows due to degraded lands. Rehabilitating the land and other soil and water conservation measures improved water productivity. Another constraint was the energy

Katrien Descheemaeker

Mats Lannerstad

livestock lost to excessive walking to find drinking water. Constructing water-harvesting structures improved milk water productivity per cow by 35 percent.

India's dairy systems provide another example of the benefits of studying water productivity. Presenting for Michael Blümmel of the International Livestock Research Institute, who was unable to attend, Descheemaeker said that India is now the largest global milk producer, employing millions of smallholder farmers. But that dominance comes with a huge environmental burden.

Water productivity of India's dairy systems is low. Research suggests the reasons are a combination of low water productivity to grow the crops that make up more than half the feed source; herds made up primarily of low producing breeds; and, as in Ethiopia, livestock energy expended on maintenance rather than producing milk.

Increasing the productivity of each animal would reduce the number of animals needed, thus reducing the resources required. Feeding animals more crop leftovers, which adds no water burden to feeding livestock, alongside nutritional supplements, would also substantially reduce the industry's toll on water resources.

Brad Ridoutt, of Australia's Commonwealth Scientific and Industrial Research Organisation, said that as livestock systems are improved, it's crucial to understand the entire lifecycle of the system, so that environmental burdens aren't shifted elsewhere. Better feed, for example, may send animals to market sooner, thereby reducing greenhouse gas emissions, but may require increasing irrigation and water use to achieve it.

He uses a life cycle assessment approach to understand the role of livestock products in a sustainable food system. Life cycle assessments consider all relevant environmental impacts to identify potential trade-offs and avoid narrowly focused actions that shift burdens up and down the supply chain.

From left: Brad Ridoutt and Deb Hamernik

Ridoutt described a cattle case study comparing the water footprints of six different beef systems in Australia. It determined how water use in each

Global Perspectives on Livestock and Water

system contributes to water scarcity by using the local applicable water stress index. Results from life cycle assessments demonstrate that agriculture is not homogenous, he said, and such in-depth assessments have much to contribute in identifying strategies to reduce environmental impacts and how to make food production systems more sustainable.

> *" If we improve productivity, if we care for our animals the best that we can in whichever system, we will cut water use and have a more sustainable future."*
>
> *Jude Capper*

Environmental Stewards

Colorado rancher Duke Phillips said ranchers often take the blame for abusing the land, but abuse is often the result of drought or economic downturns. As the owner of two diversified businesses that include tourism, Phillips is able to weather ranching stresses and reduce stocking rates to preserve natural resources when necessary.

Speaking during the panel "A View from the Field," he and Nebraska rancher Mike Kelly said they see themselves as stewards of the land. "I've come to see ranchers as one of the best alternatives for resolving some of the ecological issues that we face today that are so monumental," Phillips said. "Because we live on the land, we have a lot at stake."

Although cattle is his primary business, the ranches he manages — the 85,000-acre (34,400-hectare) Chico Basin Ranch and 103,000-acre (41,700-hectare) Medano Zapata Ranch — also serve to educate people about the land and ranching to encourage understanding and support for conservation.

Banker and rancher Kelly also sees conservation as an integral aspect of ranching. His goal, and that of most ranchers in Nebraska and around the world, is to leave the land in better condition for the next generation, he said.

He described a multi-organizational project to restore a nearly two-mile section (3.2-kilometer) of a stream that had been degraded after a previous owner straightened it. "The change there was unbelievable," he said of restoring it to its historic course, which raised the water table, rejuvenated wetlands and increased grass production.

Kelly's ranch is located in the Nebraska Sandhills, which lies above the High Plains Aquifer and where more than 20,000 square miles (52,000 square kilometers) of sand dunes naturally filter the water. He said this natural treasure is threatened by urban sprawl, wind energy farms and converting grasslands to cropland.

"Livestock and Water" panelist Jerry Volesky, of the University of Nebraska-Lincoln, said that croplands are indeed encroaching on grasslands in the U.S. Great Plains. Despite the land decrease, as well as a reduction in the number of cattle and calves, red meat production has increased slightly

Jerry Volesky

Cattle grazing in the Nebraska Sandhills

thanks to productivity gains. The most limiting factors to continued improvements in efficiency and sustainability are water availability and variability for grassland production, he added.

Conclusion

The livestock industry plays an enormous role in the economy and culture of many countries, which can't be ignored, said Lannerstad. Livestock contributes about 40 percent of the global value of agriculture. Twenty percent of the world's population, most of them smallholder livestock keepers, and 1 billion of the world's extreme poor, depend on livestock for their food and livelihoods.

Increasing water efficiency in crops grown for feed, using more crop residue as feed, improving animal nutrition, switching to more productive breeds and managing grasslands more efficiently are all ways to continue improving the industry, though understanding local conditions is critical to making appropriate recommendations.

Increasing productivity is key to reducing the industry's burden on natural resources no matter what system is involved, Capper emphasized. "If we improve productivity, if we care for our animals the best that we can in whichever system, we will cut water use and have a more sustainable future."

Six

Sharni Jayawardena, IWMI

Views from the Field

The world relies on farmers and ranchers to meet its growing demand for food, but too often they are left out of agricultural research and policy decision processes, particularly in developing countries.

In the U.S., producers have access to the latest technology, research and educational programs from an extensive network of extension offices affiliated with public, land-grant universities located in each state. But in most areas of the world that kind of support network doesn't exist.

The conference explored a view from the field from three perspectives: producers, the U.S. extension service and researchers engaged in participatory research, which is designed to include farmers, policymakers and other local stakeholders in research planning, execution and outcome assessment.

Producers

In 2010, after eight years in international supply chain management, Antonio Ferreira of Brazil took over the ranching operation his grandfather had started. Today, he manages two ranches, totaling 2,000 animals, that encompass the entire livestock chain, from birth to sales negotiation and slaughter.

"I think my logistics background has helped me tremendously in improving my business," Ferreira said. He conducts tests, analyzes his operation's performance and provides frequent trainings for his employees. He also began using mixed breeds that combine greater productivity with better adaptation to the tropics. These improvements have reduced the selling age, thus lowering costs and improving profits.

Nebraska ranchers rounding up cattle

Ferreira is a board member of Novilho Precoce, an association focused on high-quality beef for the Brazilian market. In 2012, members sold 138,000 animals. Brazilian beef is entirely grass-fed, Ferreira said. While the carcass weight is 300 pounds (136 kilograms) less than the typical U.S. corn-fed weight, the expense to obtain that additional weight wouldn't be economical, particularly given that the biggest consumers of Brazilian beef — Brazil, Russia and Iran — prefer grass-fed, he said.

Nebraska farmer Ken Schilz said that most Nebraska beef is finished on corn-fed rations to fatten them and get them to market in as short amount of time as possible. "We've had to become more efficient in feeding the animal because that's what the consumer demands," said Schilz, a state senator whose family owns cropland and a cattle feedlot in west-central Nebraska started by his grandfather.

He described how changes in corn use, from cracked corn to corn gluten, has allowed greater animal production efficiencies. Better feed and more productive breeds have increased his family's production from his grandfather's 900-pound (408-kilogram) Hereford, to an average 1,500-pound (680-kilogram) Angus.

Views from the Field

Unlike the other panelists, Duke Phillips lives a much different life than the one in which he was raised. He said he considers his isolated childhood on a Mexican ranch, where people had to survive off the land, a blessing. Now, he lives on a ranch just two hours from Denver, Colo.

But location isn't the only change for Phillips. He said he once considered people a threat to his ranching way of life, but now he sees them as potential allies to preserve ranching and the environment. "As I have come closer in contact with our society and being a professional rancher, my goals have changed from trying to create my own world out away from everyone … to trying to create an opportunity for people to get together and learn from each other."

Phillips owns Ranchlands, a diversified business that manages two ranches, totaling 200,000 acres (81,000 hectares), and provides hospitality, educational programs and ecotourism, among other activities. The diversity allows him to educate urbanites about rural life as well as supplement his primary cattle-producing business. He said he considers conservation an integral part of his ranching operations.

Nebraskan Mike Kelly shares Phillips's conservation outlook. He grew up on a ranch started by his grandfather at the southern end of the Nebraska Sandhills, 20,000 square miles (52,000 square kilometers) of natural sand dunes sitting atop the High Plains Aquifer. Kelly's son now lives on the family's 20,000-acre (8,000-hectare) ranch.

Kelly said his family understands they ranch part of the largest intact prairie left in North America, which also provides important functions for the land and the aquifer. "I think we, as Nebraskans, recognize the beauty of the Sandhills," he said. "We also recognize we are stewards of that treasure, and

From left: Antonio Ferreira, Mike Kelly, Ken Schilz, and Duke Phillips

Charles Hibberd

we need to protect and preserve that area of the Sandhills and the aesthetic values of that landscape."

Kelly cites threats to the area, such as urban sprawl, fragmentation and loss of prairie to cropland. But he said opportunities exist for ranchers to contribute positively. "I think ranching and stewardship go together," he said. "And I know that an opportunity exists for ranchers to work with various conservation partners, and they're willing to do that." The Kelly family has won numerous honors for its conservation efforts.

UNL Extension

Kelly said he's fortunate to benefit from the University of Nebraska's research and extension office, which works closely with ranchers. During his plenary talk, Charles Hibberd, dean of UNL Extension, said such collaborations are key to fulfilling its mission. The old model of extension, in which only agents were the experts, never worked. Collaborations among producers, UNL researchers, natural resources districts, communities and private partners are crucial to finding workable solutions.

In 1914, U.S. congressional law tasked land-grant universities in each state with transforming research-based programs into usable formats. "UNL Extension is committed to advancing the knowledge and practice of Nebraskans," Hibberd said. "We are committed to being a relevant and reliable source of research-based information."

Extension offices throughout the state help build trust and partnerships with local communities and farmers, and ensure that agents and researchers understand local needs. Trust also helps agents encourage adoption of best management practices and the latest technology, which improves farmers' efficiency and conserves the state's resources, he said.

> *"I think ranching and stewardship go together."*
> *Mike Kelly*

UNL's Nebraska Agricultural Water Management Network is an example of bringing research to practice. Created to help farmers better manage irrigation through soil water content monitoring, the network has significantly decreased pumped withdrawals from the aquifer in participating farm fields. Extension's network and educational programs helped the program expand from 15 farmers in 2005 to 850 by 2012.

UNL Extension continues to expand its reach, adopting social media, web tools and new technologies to engage communities and producers, Hibberd said.

Research in Action

Because most global food demand will continue to rely heavily on farmers already struggling to

Views from the Field

produce food on less than 10 acres, agricultural development, a high priority for the Bill & Melinda Gates Foundation, must involve smallholder farmers from the outset, said Jeff Raikes, CEO of the Bill & Melinda Gates Foundation.

"We believe very strongly that you have to include the voices of these farmers, their families, in the work that we do," he said. "So figuring out how to have that kind of participatory research is very important." Raikes moderated a panel of participatory researchers working in diverse parts of the world.

Panelists agreed that understanding farmers' needs should be the first step, but is frequently ignored. "We often start with our own expertise and see if farmers need that, but the idea is to start the other way around," said Aditi Mukherji of the International Centre for Integrated Mountain Development in Nepal. "Much of my work is about understanding farmers' behavior, finding links with the broader policies that frame their behavior and then to inform policy in such a way that farmers benefit."

"We believe very strongly that you have to include the voices of these farmers, their families, in the work that we do."
Jeff Raikes

Mukherji applied that process in a West Bengal, India, community where it had been assumed that water scarcity was due to lack of water, but actually stemmed from high energy costs preventing access to water. Understanding farmers' needs eventually led to important changes in groundwater and electricity policies. For her work, Mukherji was awarded the 2012 Norman Borlaug Award for Field Research and Application, given by the World Food Prize Foundation.

Karen Villholth, of the International Water Management Institute in South Africa, described her work with the AgWater Solutions Project, a multi-institutional effort to find water management solutions for smallholder farmers in India and five Sub-Saharan African countries. The project, funded in part by the Gates Foundation, is seeing success because of a well-planned engagement process that includes everyone from farmers to people influential with high levels of government, she said. That engagement helps ensure governments take appropriate action.

Paul Hicks, who works on Central American agricultural issues for Catholic Relief Services, agreed that that kind of government involvement is necessary. Many solutions are already known, he said, but the knowledge is dispersed and often doesn't affect policy. "Our theory is that if we can get these decision-makers together, then we can come up with recommendations that there's consensus around. And by including policymakers, there's more likely to be policy changes as a result of this process."

His organization is a member of the Global Water Initiative, a multi-organizational effort to address water issues globally. In Central America, Hicks is bringing policymakers, development specialists and researchers together to look at agricultural programs implemented five to 15 years ago to see what worked, what didn't and why.

From left: Paul Hicks, Aditi Mukherji, Karen Villholth, Ravinder Kaur and Jeff Raikes

Ravinder Kaur, of the Indian Agricultural Research Institute, said an important aspect of any solution is to understand the local context. India faces many unique challenges that require complex, site-specific solutions. Her center develops adaptive strategies that go beyond agricultural and livestock research to also address socio-economic issues and capacity building.

Conclusion

Producers and researchers recognize that the market drives food production. Phillips, the Colorado rancher, said any changes have to provide strong economic incentives, and researcher Mukherji agreed. Farmers grow rice in many parts of India because it gives them 50 percent more return than the next profitable crop, even though it damages the semi-arid environment, she said. "The idea would then be how to make that next profitable crop more profitable than rice… I think market has to take a driving seat."

In Sub-Saharan Africa, policies are optimistically focused on increasing agricultural production and irrigation. But Villholth urged addressing future environmental consequences as well. Using fewer resources benefits farmers and the environment, and by transferring more responsibility to farmers, they will be more inclined to take care of the environment as well.

"You actually can watch the corn grow."

Michael Forsberg

Seven

Michael Forsberg, Platte Basin Timelapse Project

Cool Tools and Technologies for Ag and Water Research

Advanced technologies in data gathering and analysis are leading to a greater understanding of the world. In agriculture and water management, these new technologies are expanding data collection in remote and difficult locations through digital sensors, images and sampling. Better access to more accurate and timely information allows researchers, farmers and resource managers to make better decisions, which improves yields and conserves resources.

The University of Nebraska-Lincoln is developing tools that collect information on soil moisture, water flow, weather and land use changes in new ways, and can also send the information wirelessly, analyze it and put it into user-friendly formats that encourage adoption.

And, yes, they're cool too.

Platte Basin Timelapse Project

While traveling throughout Nebraska in 2010 on a documentary project, photographer Michael Forsberg and Nebraska Educational Telecommunications producer Mike Farrell wondered what could be learned about the Platte River watershed if it were viewed in its entirety. They conceived of the Platte Basin Timelapse Project, placing more than 40 cameras along the entire length of the Platte River, from the headwaters in the Colorado Rockies to its confluence with the Missouri River. Each day, the cameras take a picture every daylight hour, documenting the river through time-lapse photography.

Mike Farrell (left) and Michael Forsberg

From left: Steve Goddard, Mike Farrell, Ian Cottingham, Sebastian Elbaum, Can Vuran and Michael Forsberg.

"These cameras are providing us a view that we've really never seen before," Forsberg said. The visual data give scientists, resource managers and the public a greater understanding of the influences agriculture, municipal water supplies, geological processes, restoration projects and other activities have on the watershed. "You actually can watch the corn grow," Forsberg joked.

The project captured the major flood of 2011 and the record drought in 2012. Tying the images to other data, such as water quality and crane populations, helps researchers better understand extreme events and their consequences.

To wrangle the tremendous amount of digital data generated, software architect Ian Cottingham and students from UNL's Jeffrey S. Raikes School of Computer Science and Management are developing user-friendly software that enables researchers and the public, including schools, to easily create videos, add datasets, annotate or manipulate the images, and create their own narratives about the river.

Cool Tools and Technologies for Ag and Water Research

Ian Cottingham

Photography is a powerful communication tool, Forsberg said. "What we're really trying to do is build a community around a watershed," a single community that extends from the Colorado mountains to the prairies of eastern Nebraska.

Wireless Underground Sensor Network

The more information about soil, air and plant conditions farmers can access, the better equipped they are to increase yields and conserve water. Soil moisture sensors, used on some farms for two decades, significantly improve irrigation use. The problem, said UNL computer engineer M. Can Vuran, is getting the data out of the fields.

Current remote soil monitoring sensors require nearby towers to transmit sensor data via a cellular system to a base station where the information can be analyzed and acted upon. While a significant improvement over previous efforts, the system is expensive, towers create obstructions in the field, and deployment and maintenance are difficult and time-consuming. These factors have limited adoption of decision-based tools to only 8 percent of growers, Vuran said.

To overcome these barriers, he's developed an underground wireless sensor network that wirelessly sends data from sensors buried in the soil to a center pivot irrigation system or base station. The network provides lower cost, real-time soil information. The center pivot, for example, can receive sensor data to initiate irrigation or to adjust water levels as it moves around the field. Data can also be analyzed later to evaluate best practices.

Vuran and his colleagues are commercializing the product. But he's also working on improvements, such as combining underground sensor data with other datasets for more accurate, reliable information and developing permanent sensors that don't require removal or replacement.

M. Can Vuran

Unmanned Aerial Vehicles

Although unmanned aerial vehicles (UAV), or drones, often bring to mind military weapons, they serve many other, non-lethal purposes. Crop cams, for example, are small, fixed-winged aircrafts launched by hand that can take pictures over a few acres to help farmers gather data normally done by plane. Crop cams aren't automated, however, and lack other valuable features.

Sebastian Elbaum

UNL computer scientists Sebastian Elbaum and Carrick Detweiler are developing UAVs to aid farmers and researchers. "A lot of people are trying to capture data, and they cannot do it effectively," Elbaum said.

They showed off their UAVs live at the conference, along with videos demonstrating the UAVs' many uses, such as capturing images of entire fields or zooming in on individual plants or leaves. Researchers also can use drones to peer into places otherwise difficult to see, such as observing swallow behavior under a bridge.

But Elbaum and Detweiler said they want to go beyond images. They're developing methods to interact with the environment, such as collecting water and air samples or leaf clippings. They also envision more complex tasks, such as measuring crop height, small-scale herbicide application and wirelessly gathering sensor data or transferring power to recharge sensors.

They are currently working to simplify operations, make the UAVs more reliable under windy and other adverse conditions, and enable multiple UAVs to work together safely and reliably.

"UAVs come in all shapes and forms and users," Elbaum said. "We think these steps are just the beginning."

Audience members raised concerns about privacy with these and other new data-gathering technologies. UNL computer scientist and interim dean of the College of Arts and Sciences, Steve Goddard, who moderated the panel, said that any new technology that collects and stores information raises fears about privacy and how the information would be used. Ultimately, he said, technologies are just tools; it's how we use them that's important.

Carrick Detweiler

Eight

Conclusions

To solve many of the problems examined in detail at the 2013 Water for Food Conference — from climate change to livestock productivity — presenters frequently cited the need to build relationships. While partnerships are increasingly promoted as a key component to solving complex global issues, experts made clear that collaborations must go beyond like-minded groups with similar goals. To succeed in creating food and water security into the future, collaborations must bridge scales of focus and discipline.

Spanning these bridges is a difficult and lengthy process, they warned. Stakeholders include farmers large and small, researchers, resource managers, policymakers at all levels, among others, each with differing concerns, experiences and worldviews. Finding common ground and building trust is the first step in developing successful collaborations, experts said.

Farmers, the ultimate stewards of 70 percent of the world's freshwater resources, are the least consulted. Presenters acknowledged the benefits of engaging farmers in the research process, from a greater understanding of local conditions to developing better, more acceptable solutions.

Prem S. Paul

In one example, listening to farmers in West Bengal, India, completely altered long-term assumptions about the cause of water scarcity. Later, engaging policymakers led to important water and energy solutions for the region.

> *"The scientists can only get us so far. At the end of the day, the choices, the trade-offs, turn on social values and priorities, and that's not a scientific question."*
>
> *Sandra Zellmer*

For the U.S. agricultural extension service, collaborations are the foundation of its work and their effectiveness requires building trust. UNL's extension offices build this trust by being located in communities and staffed with people who can bridge research and local needs. Ranchers described their own relationship building: Duke Phillips put aside his reticence at engaging the public to embrace tourism and educational programs, and Mike Kelly encouraged reaching out to environmental groups and governmental agencies to support conservation efforts.

Engaging decision-makers also was frequently raised as a critical element at both global and local scales. Whether helping ranchers or communities prepare for drought, transforming systems into healthier regimes or tackling international climate change agreements, decision-makers often hold the key to successfully implementing necessary changes. Persuading decision-makers sometimes requires leveraging the public's support, several presenters noted, so communicating effectively with the public can't be overlooked.

Conclusions

Technology also will play a key role in increasing water and food security, particularly as drought and other weather extremes increase worldwide. The conference featured technological advances on several fronts, from biotechnology and modeling to precision irrigation and information tools.

> *" Solving any problems in isolation won't work in the future."*
>
> *Dilip Kulkarni*

But new technology must reach the fields, and knowledge must flow to where it's needed, said Dilip Kulkarni, of Jain Irrigation Systems Ltd in India, during the closing panel. That level of sharing requires collaboration. "Solving any problems in isolation won't work in the future," he said.

Another theme that emerged across conference topics was recognizing trade-offs. Changes, however beneficial to some, often have consequences that ripple out far from the system or scale targeted. Sometimes unrecognized, these consequences can trigger tipping points and regime shifts. One dramatic example described a South African policy to send children to school that contributed to a loss of grasslands and pastoral livelihoods. In another example, hydroelectric dams that provide welcomed energy sources can have detrimental impacts on fishery ecosystems and the livelihoods that depend on them.

Recognizing that enhancing food production can shift burdens by changing the landscape, hydrologic cycle or even cultural systems, a number of presenters described methods to incorporate resilience, life cycle assessments or other whole system research into their work.

Mace Hack, state director of the Nature Conservancy in Nebraska, said during the closing panel that he's encouraged by the agricultural community's move toward incorporating a larger focus. Conservationists have similarly shifted from a species or region specific focus toward more whole ecosystem stewardship, and he anticipates more integration between the two fields. "It gives me hope that there's a confluence of interest there that can be well developed in not only understanding how to produce more food, but how to also preserve the natural systems that are so important to preservation of both nature and people," he said.

Climate change is also forcing trade-offs, several experts said. As the repercussions of climate change become unavoidable, societies must adapt for long-term survival. How societies proceed is a question of values, such as whether to rebuild in coastal or flood zones after an extreme event or, at a larger scale, whether and how to develop alternatives to carbon-based energy sources.

Dilip Kulkarni

From left: Roberto Lenton, Mace Hack, Dilip Kulkarni, Prem S. Paul and Sandra Zellmer

"The scientists can only get us so far," said UNL law professor Sandra Zellmer, during the closing panel. "At the end of the day, the choices, the trade-offs, turn on social values and priorities, and that's not a scientific question."

The issues surrounding water for food are complex and interrelated; they are globally significant yet locally specific. So bringing together all stakeholders, at all scales, is critical to encompass that complexity and to find solutions, DWFI director Roberto Lenton said during the closing panel. The annual Water for Food conferences strive to capture that mix of stakeholders to encourage understanding, trust and new collaborations among participants who work in different parts of the world, on different problems, but ultimately toward the same goal.

Jim Gaffney congratulates Audrey Boerner for her first place finish in the Online Competition

Appendix

Juried Poster Competition

The 2013 Water for Food Conference featured a juried poster competition for graduate students. Thirty posters were entered in categories reflecting the major conference themes: Climate Change Science and Climate Extremes; Climate Resilient Crops: Drought, Flood and Heat Tolerance; Communicating Science Related to Water for Food; Livestock and Water; Resilience in Socio-ecological Systems; Resilience in Stressed Watersheds and a general category for other topics related to water for food. Faculty, partners and other professionals submitted an additional 17 posters. Photos of the winners present are included. Award winners are pictured with Jim Gaffney of Pioneer Hi-Bred, a DuPont company, which co-sponsored the competition.

Online Competition

Donald Pan (right) with Jim Gaffney

Daran Rudnick (right) with Jim Gaffney

University of Nebraska faculty served as jurors for an online competition held before the conference. All winners received cash prizes and free registration for next year's conference.

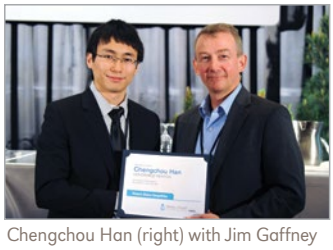
First Place ($1,500): Audrey Boerner, UNL, Rapid Hydrochemical Evolution of River and Groundwater During 2012 Drought Conditions, Platte River, Nebraska

Second Place ($1,000): Donald Pan, UNL, Production of Viral Like Particles (VPLs) Following In Situ Stimulation of a Subsurface Microbial Community

Third Place ($750): Daran Rudnick, UNL, Impact of Water and Nitrogen Management on Maize Yield, Crop Water and Nitrogen Productivity, and Evapotranspiration-Nitrogen Use Efficiency Index

Viewer's Choice Competition

Tarlan Razzaghi (right) with Jim Gaffney



Chengchou Han (right) with Jim Gaffney

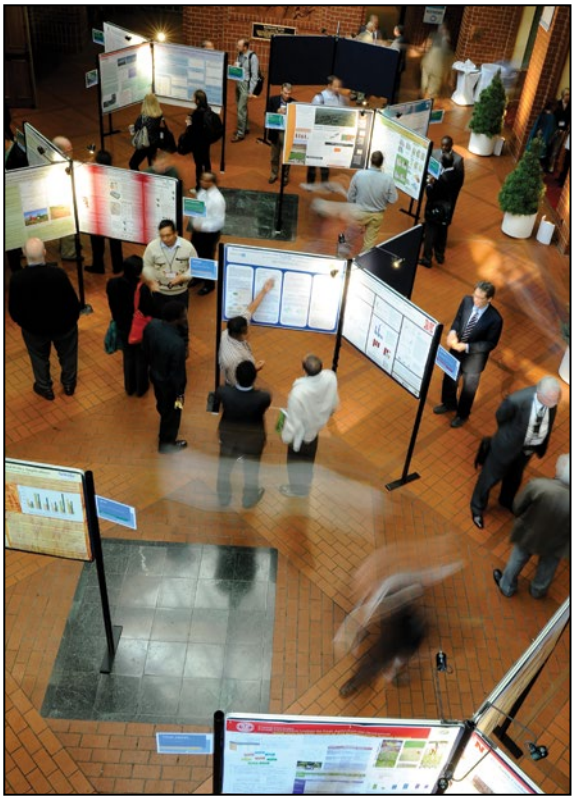
In the viewer's choice competition conference attendees voted for the best poster during the poster session and reception sponsored by DuPont Pioneer Hi-Bred. Winners received cash prizes and free registration for next year's conference.

Winner ($1,500): Tarlan Razzaghi, UNL, Estimating Spatial Variability of Reflectance and Propagation of Uncertainties in Vegetation Indices within LANDSAT and MODIS Pixels

Honorable Mention ($750): Chengchou Han, UNL, Developing Corn-Soy Water: an Online Irrigation Decision Aid for Corn and Soybean

Conference Photos

Harvey Perlman, Chancellor, University of Nebraska-Lincoln



Poster Sesson

James B. Milliken, President, University of Nebraska

Joseph Starita, author and banquet speaker

Daryl White Trio

From left: Ravinder Kaur, Harkamal Walia and Tom Farrell

Informal Reception

Conference Photos

Jeff Raikes and Mogens Bay

Carrick Detweiler flying drone during presentation