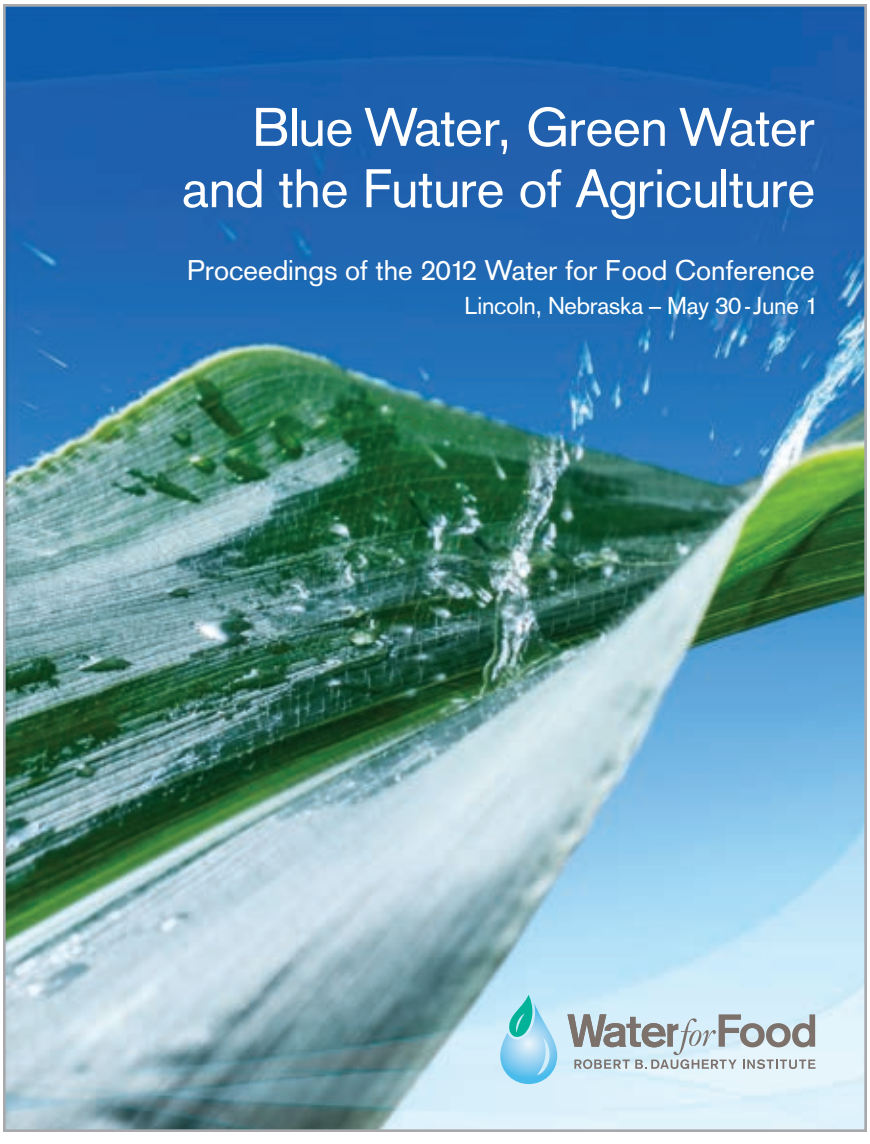
Blue Water, Green Water and the Future of Agriculture

Proceedings of the 2012 Water for Food Conference

Lincoln, Nebraska – May 30 - June 1



Water for Food

ROBERT B. DAUGHERTY INSTITUTE

Proceedings of the 2012 Water for Food Conference, May 30-June 1, 2012, Lincoln, NE.

Citation:
University of Nebraska–Lincoln Office of Research and Economic Development (2013). Proceedings of the 2012 Water for Food Conference. Lincoln.

ISBN: 978-0-615-73973-1

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Major conference support underwritten by
Robert B. Daugherty Charitable Foundation

Generous conference support provided by
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Monsanto
Syngenta

Additional conference support provided by
Pioneer, a DuPont Company
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Foreword

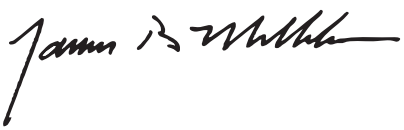
In May 2012, as we convened the fourth global Water for Food Conference in Lincoln, Neb., record-setting crop yields were being forecast for U.S. farmers. By August, a historic drought had engulfed one-third of the nation, driving up grain prices and confirming the linkage between water and food security and the need to address this complex challenge on a global level.

The focus of the 2012 Water for Food Conference, "Blue Water, Green Water and the Future of Agriculture," was relevant globally and certainly in Nebraska, where agriculture relies equally on blue and green water. Forty-six percent of Nebraska's crops are irrigated with "blue" water from the High Plains Aquifer and rivers and streams; the other 54 percent are rainfed, depending on "green" water.

Nebraska farmers, like farmers across the globe, are seeking new ways to make every drop of water count, whether through improved crops, advances in irrigation or new tillage and cropping systems. The mission of the Robert B. Daugherty Water for Food Institute is to move innovative research, technologies and ideas out of the laboratory and into the hands of farmers and resource managers through creative partnerships with private and public sector organizations throughout the world.

The Water for Food Conference, hosted by the University of Nebraska with major support from the Robert B. Daugherty Charitable Foundation, the Bill & Melinda Gates Foundation, Monsanto and Syngenta, brought together about 500 people from 28 countries working to ensure water and food security. We heard from small- and large-scale farmers, plant scientists, industry leaders, natural resource managers, government officials and many others. This report documents the ideas and discussions that emerged from the conference.

We can develop effective solutions only by hearing the perspectives of the many sectors involved. We hope this report will encourage you to join the discussion.



James B. Milliken, President
University of Nebraska

Jeff Raikes, CEO
Bill & Melinda Gates Foundation

Preface

As these proceedings make clear, the fourth global Water for Food Conference, "Blue Water, Green Water and the Future of Agriculture," was exceptionally successful. We were fortunate to attract an array of distinguished speakers who spoke with authority on the main theme of the conference. The Agricultural Producers Panel, the Industry Leaders Panel, and the Women, Water and Food Panel all provided extraordinary insights, and the special session on innovative water governance in Nebraska and Brazil highlighted the critical role of governance in ensuring effective management of water for agriculture. The technical sessions on groundwater assessment and crop technologies in tough environments allowed participants to discuss these critical issues in depth, while the closing panel session provided an opportunity to reflect broadly on several profound cross-cutting issues that relate to the challenge of transforming agricultural water management in the years to come.

A highlight of the conference was the special tribute to the State of Nebraska's 23 Natural Resources Districts (NRD) on their 40th anniversary. NRDs have played a critical role in the management of water for food production since their establishment in 1972. In my view, the NRDs are a wonderful example of innovative groundwater governance with global relevance and represent an outstanding opportunity for Nebraska to contribute to national and international discussions of ways to improve the governance of water.

This year, the conference attracted a record number of participants from Nebraska, other parts of the U.S. and 28 countries around the world. The conference highlighted how our new institute can foster global policy debates on improving the management of water for food security. It also reinforced ways we can take advantage of our location in the center of one of the world's most important food producing areas to address water for food issues, both locally and globally in other regions facing critical challenges. I was personally struck by the way this conference helps build bridges across the worlds of largeholder and smallholder agriculture and across the water, agriculture and livestock communities, which too often move in different circles.

In closing, I would like to pay a special tribute to Prem S. Paul, vice chancellor for research and economic development of the University of Nebraska–Lincoln, for his vision and extraordinary leadership of this conference and the three that preceded it. He and his staff, who willingly gave so much of their time to make sure the conference was a great success, have set an extraordinarily high standard for the future. I also would like to acknowledge with thanks the Robert B. Daugherty Charitable Foundation, Bill & Melinda Gates Foundation, Monsanto, Syngenta, Pioneer and Global Harvest Initiative for their generous financial support for the conference.

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

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Hosted by the Robert B. Daugherty Water for Food Institute (DWFI) at the University of Nebraska (NU) and the Bill & Melinda Gates Foundation, the 2012 global conference – "Blue Water, Green Water and the Future of Agriculture" – brought together about 500 experts from the world's universities, private sector, governments and nongovernmental organizations to discuss issues and propose solutions to growing more food with less water. Presentations and panel discussions offered innovative ideas and research and provided a forum to discuss varying viewpoints on solving the water for food challenge.

Plenary Presentations

"The issues … of water for food essentially transcend so much of what is driving the world today," said Roberto Lenton, DWFI founding executive director. Trends in global food demand and water availability – two sides of the water for food equation – point to the need for growing more food with less water. These trends vary regionally, so cookie-cutter approaches won't work.

Platte River, Nebraska

Additionally, water for food challenges manifest uniquely at different scales, from the household to the global. People working at different scales must interact and work across disciplines to understand each other's viewpoints. DWFI's vision and activities help people working at all scales come together and find innovative solutions, Lenton said. Nebraska and NU have a long record of agricultural innovation and engagement in water for food issues at state and global levels. That experience and NU's commitment to interdisciplinary partnerships allow the institute to build on this background. DWFI is envisioned as a three-legged stool of research, education and policy advice. "The three are absolutely fundamental, and it's the combination of the three that will make this institute really add value," Lenton said.

Malin Falkenmark, Stockholm International Water Institute (SIWI) senior scientific adviser, said countries' green and blue water flows vary greatly. Essentially, blue water is the water in rivers, lakes and aquifers, and green water is the precipitation stored in the soil. Incorporating green water into a country's water balance can alter its water picture. Countries with too little blue or green water to support rainfed or irrigated agriculture, which are projected to represent nearly half the world's population in 2050, must increase cropland, import food and improve water productivity. Additionally, increasing global food consumption, particularly of meat, is unsustainable. Reducing calorie and meat consumption would allow water-short countries to meet food needs. Yet SIWI studies indicate that no low-income country will be able to support its population by 2050. Other studies demonstrate that disturbances in water flow diversions cause major environmental

Farmer in Western Nepal

problems, including desertification, salinization and savanization. Agriculture also depletes groundwater and rivers. To secure environmental flow, consumptive use for agricultural production and other societal needs would have to be limited, she said.

Colin Chartres, director general of the International Water Management Institute (IWMI), agreed that blue water reductions due to increasing irrigation are worrisome. "I think one of the great challenges … is really looking at whether or not we can sustainably intensify agriculture in harmony with the environment," he said. In describing IWMI's contributions, Chartres said the institute initially worked on developing participatory water management systems and evolved into investigating river basin hydrology and integrated water resource management.

More recently, IWMI's 2007 Comprehensive Assessment demonstrated that many countries are economically water scarce, and additional modeling studies demonstrate that global demand will exceed supply by 2040. Given these studies, Chartres raised the global paradox of feeding 2 billion more people using the same or less water in an era of climate change. He offered several solutions: reduce waste, encourage trade, increase productivity and promote healthier diets that consume less.

Water is an important commons because it connects people, said Ruth Meinzen-Dick, International Food Policy Research Institute senior research fellow. She described Elinor Ostrom's principles for enduring commons: clearly defined user and resource boundaries; congruence with local conditions and between contributions and benefits; collective choice

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arrangements; monitoring of users and resources; graduated sanctions; conflict resolution mechanisms; minimal recognition of the right to organize; and nested enterprises. Many factors weaken collective action, but it can be strengthened through steps such as hiring facilitators, participatory planning methods, policy and institutional reforms, government collaboration with groups, and incentives that empower resource management. Property rights to water and infrastructure also empower people. Rights may involve ownership or aspects of use, such as decision-making, exclusion and alienation. These rights can come from state law, religious law or social norms, all of which often interact, creating dynamic situations.

The definition of yield has shifted from grain per grain, which is a plant's capacity to multiply grain, to kilos per hectare as agricultural land has become limited, said Victor Sadras, principal scientist at the South Australian Research and Development Institute. This change results in trade-offs from individual crop production to system production as well as in single versus double cropping. Studies show that growing soybeans after wheat reduces soybean yields but increases overall productivity because more water and photosynthetically active radiation are captured. Therefore, rearranging crops in space and time makes production gains possible, he said.

"The issues … of water for food essentially transcend so much of what is driving the world today."

Other studies suggest nitrogen deficiency may cause gaps between potential and actual yields. A trade-off exists between water use and nitrogen use efficiencies. Shifting the yield gap interpretation to include nitrogen as well as water may be more profitable and is important to consider in countries with chronic nutrient deficiencies.

Women farmers in East Africa

Charles Iceland, senior associate at the World Resources Institute, described the institute's Aqueduct project, a database and set of practical tools designed to provide detailed global water information. Based on an adaptable framework of indicators, the project helps users better understand water risk at local and global scales and facilitates public and private action to promote more efficient and sustainable water management, he said. Indicators include the water stress ratio, water quantity, water quality and water management quality in specific river basins worldwide. One recent study showed that globally more than a quarter of total cultivated crops and 40 percent of irrigated agriculture are located in water-stressed areas. By 2025, water stress will worsen two to eight times for half the current global total of cultivated crops and for nearly three-quarters of irrigated crops. Regional figures are similar to global averages.

Panel Discussions

Agricultural Producers Panel – A View from the Field

The University of Nebraska–Lincoln's (UNL) Mark Gustafson hosted a panel of farmers who represent a spectrum of geographies, sizes and operations. Guillermo Belottini, commercial manager of LIAG Argentina, described the company's sustainable agricultural practices on Finca Tolloche, where it grows cotton, wheat, maize and soybeans on 41,000 hectares (101,313 acres), 60 percent of which are irrigated. To improve water efficiency, the farm uses mechanized linear irrigation systems to draw river water, laser levels its fields and uses capacitance probes. To protect soils, the farm uses no-till and stripper heads and plants wheat during the driest season. Genetically modified varieties have improved weed control, and new precision farming strategies, such as yield monitoring and fertilizer variable rate applications, have increased production.

April Hemmes operates a 1,000-acre (404 hectares) rainfed Iowa farm, where she grows corn, soybeans and hay and has a cow-calf herd. Equipment advances allow Hemmes to farm by herself, and she said seed genetics have made her "a really good soybean farmer." To remove excess water from her fields, she installed tile drainage systems. Wetlands, buffer strips and riparian areas reduce phosphorous and nitrogen runoff, and the federal government compensates her for setting aside unusable land as a wetland. Nitrogen and phosphorus runoff concerns will motivate farmers to use nutrients even more precisely, but Hemmes said she worries about potentially restrictive policies in the future.

Brandon Hunnicutt lives on a 2,600-acre (1,052 hectares) fully irrigated Nebraska farm, raising corn, soybeans and popcorn with his brother and father. Traditionally flood irrigated, the farm started using center pivot irrigation systems in the mid-1970s. After the introduction of genetically modified crops, the Hunnicutts began strip tilling to ensure a firm seed bed for the next season and to retain crop residues for water conservation. Over time they began using variable rate planting, fertilizing and irrigating, as well as watermark sensors and capacitance probes. They found that irrigating less often didn't affect yields. Farming has become more mental than physical, Hunnicutt said. He hopes better understanding of water, crop and soil interactions will lead to even greater productivity.

Ripening wheat

Indian land reforms in 1947 that limited landholding sizes dramatically altered agriculture, said Mridula Sharma, who farms with her husband in Uttar Pradesh. Today, 45 percent of Indian landholdings are 1.25 acres (0.5 hectare), and 83 percent are less than 5 acres (2 hectares). Once a

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large landowner, her family now owns 25 acres (10 hectares) and primarily grows wheat and rice. The Sharmas returned to farming after raising children and use their savings to improve the operation. Tractors, harrow plows, combines and reapers have replaced manual farming. They irrigate with canal water, well water and electric tube wells. To conserve water, they leveled the land at great expense, built cemented channels to transport water and use no-till. In India, village conditions are so poor that basic needs go unmet and most farmers can't afford modern implements, Sharma said.

Industry Leaders Panel

The water for food challenge provides opportunities to work together in new ways, said Jeff Raikes, CEO of the Bill & Melinda Gates Foundation. Philanthropies can act as catalysts to stimulate interventions, which require working with both public and private sectors. Collaborations induce innovations and new approaches, and the Gates Foundation strongly believes in private sector participation, he said.

Panelists from Elanco, Monsanto, Pioneer and John Deere, representing agribusiness leaders, agreed collaborations are critical. As members of the Global Harvest Initiative, they are committed to working together to achieve food security through productivity and efficiency, said Claudia Garcia, Elanco's senior director of global corporate affairs. Panelists discussed how they are moving beyond traditional domains to encompass systems-based approaches, including working with governments and nongovernmental organizations.

Companies want a robust agricultural system and competitive marketplace in Sub-Saharan Africa to compete for farmers' business, panelists agreed. But to invest, companies need business-friendly environments that support development, including regulatory systems and basic laws or rules of accountability.

Natalie DiNicola, Monsanto's vice president of sustainable ag partnerships, notices more governmental recognition of what is required to

Improved climbing bean varieties in Rwanda

do business, but said companies must better explain their needs. There also is greater understanding that companies' innovations provide farmers with choices, and she's optimistic that public and private sectors will work together to find solutions that keep farmers' choices prominent.

John Soper, Pioneer's vice president of crop genetics research and development, said regulatory and legal systems that protect intellectual property rights provide a return on investment, thus spurring investment in new technologies and geographic regions. Where Pioneer does business is heavily influenced by countries' basic policies, including intellectual property protection laws.

Graeme Jarvis, director of John Deere's Latin America Technology Innovation Center, said solutions must provide economic benefits to growers and to the system. They also must be economically viable and sustainable for everyone, from smallholders to large commercial operations, to work effectively. "I think you'll find a lot of the solutions that are going to come on the market speak to that end."

Women, Water and Food Panel

Women produce much of the global food output, but their roles remain largely unrecognized, said Simi Kamal of the Hisaar Foundation. She led a panel of women in agriculture that included farmers, scholars and policy advocates. Ruth Meinzen-Dick said that recognizing women farmers and engaging them in decision-making would benefit families, society and the environment because women often view natural and monetary resources differently than men. UNL's Lilyan Fulginiti agreed, adding that when economists fail to consider the differences in how women and men producers think about and use water, overuse can result.

Christina Pacheco, who farms 441 hectares (1,089 acres) in southern Brazil and serves on the ORPLANA sugarcane board, demonstrated the long-range view women often take. She spoke about her willingness to set aside 40 hectares (99 acres) of land for riparian vegetation to protect her farm's waterways because "our land is the most important resource we have as farmers," adding that she needs clean water for herself and for future generations.

The panelists discussed how unequal rights affect women's food production. Women farmers own few assets or agricultural land, and lack of property rights renders them powerless. Pooja Bhattarai of Nepal's Women's Rehabilitation Centre said Nepal demonstrates how unequal rights and lack of resources affect food security: about one-fourth of the country's population is chronically underfed. Today, more Nepalese women are involved in agriculture, but women are denied ownership of land and other assets. Production is declining, but the government hasn't addressed the challenges women face.

Panelists agreed that women must assume leadership roles. U.S. farmer April Hemmes said that in her experience on agricultural boards, women prioritize their families and work more collaboratively than men. But women often are uncomfortable managing farms or participating as leaders, so developing women-only programs is important, she said.

Mma Tshepo Khumbane, a South African grassroots activist and small-scale farmer, recognizes the power of mobilizing poor women. She grows food on a 222-square-meter plot using a water management scheme she developed that includes ditch irrigation, a borehole, rainwater catchments and gray-water recycling.

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She holds mind mobilization workshops to empower women to grow crops and vegetables on their homesteads.

> *"Our land is the most important resource we have as farmers."*

Other suggestions to advance women's roles included involving women in policymaking, collective action groups and universities; in designing agricultural services and products; in protecting women's control over their economic gains; and in making investments that help women become drivers of agricultural growth and food security.

Innovative Water Governance in Nebraska and Brazil

Brazil's institutional structure and tools for managing water resources have evolved tremendously, said Oscar Cordeiro Netto of the University of Brasília. The 1997 National Water Policy views water as a public good and a limited natural resource with economic value. Water management is governed by three principles – decentralization, participation and integration – and incorporates regional, state and national plans. Civil society participates in all aspects. Early success of the Piracicaba, Capivari and Jundiaí River Basin consortium in addressing regional water issues helped establish the national framework, said Marcos Folegatti of the University of São Paulo. Today, it's structured around a unified assembly of federal, state and civil society members. Eleven chambers, totaling about 700 people, meet monthly to discuss individual topics.

Sugarcane plantation owner Christina Pacheco was an early consortium member and proponent of its riparian vegetation efforts, voluntarily replanting 40 hectares (99 acres) of riparian areas on her farm. Panelists agreed that significant challenges remain in Brazil, including increasing water services, reducing inequalities in water service access, addressing water pollution, and guaranteeing sustainable water use.

In Nebraska, the state manages surface water, while groundwater is managed by natural resources districts (NRDs), arranged around river basins and governed by locally elected officials with taxation authority. Managing surface and groundwater separately has consequences: as groundwater development increases, surface water supplies decrease, said Don Kraus of the Central Nebraska Public Power and Irrigation District. In 2004, Nebraska enacted an integrated water resources management law requiring coordinated management and annual basin evaluations, said former Nebraska Sen. Edward Schrock. Fully appropriated basins must suspend new well permits and develop an integrated management plan; over-appropriated areas also must reduce water use. To reduce groundwater use, the Central Platte NRD began a water-banking program, acquired water rights and worked with canal companies to send flows to the river, said NRD manager Ron Bishop.

Moderator Ann Bleed of UNL said endangered species in the Platte River play a large role in over-appropriated designations. To achieve greater flows to protect endangered species, a cooperative agreement among the federal government, three states and local entities was established.

The Nature Conservancy's Mace Hack said NRDs provide local accountability and encourage more efficient groundwater withdrawal monitoring.

But lack of coordination between NRDs hinders management across entire basins, and the NRDs lack a framework to facilitate more proactive approaches to water management. Panelists and the audience discussed potential solutions for improving water management, including a national water law, stronger state laws and regional compacts for large river systems.

Scientific Sessions

Two scientific sessions explored current research in water and agriculture. In the Groundwater Resource Assessment in Water-Stressed Regions session, scientists from Kansas, Australia, France and Germany reviewed groundwater modeling and management globally. In Emerging Crop Technologies for Improving Performance in Tough Environments, representatives from Syngenta, Monsanto and Pioneer discussed their companies' development of drought-tolerant products, and scientists from USDA-Agricultural Research Service and UNL described their research in aluminum tolerance genetics and epigenetics.

Closing Panel

The conference concluded with a panel discussion focusing on vital issues for DWFI. UNL's Ken Cassman discussed the importance of educating the public about the need to increase irrigated agriculture to meet food demands. He also cautioned against relying on reductions in waste and consumption to significantly offset future food demand requirements.

However, Simi Kamal of the Hisaar Foundation encouraged putting effort into reducing waste and consumption. She also offered ways DWFI could support women in agriculture, including offering platforms that encourage women to assume leadership positions.

Kingsley Dam near Ogallala, Neb.

Nebraska farmer Keith Olsen stressed the importance of maintaining farmers' choices. Biotechnology, for example, has increased production and must remain an option, he said. "I think it's extremely important … that producers have a choice to do what is best for their land and what's best for them."

UNL's Suat Irmak emphasized collaboration and said strong partnerships among industry, universities, commodity boards, farmers and crop consultants are keys to success. To have an impact, research-based information must be disseminated to growers, crop consultants and others, he added.

UNL's Prem S. Paul agreed, saying Nebraska Innovation Campus is a place for public and private sectors to work together to develop solutions and make them available worldwide. He also praised the community's engagement in the conference and urged building upon that strength. "If the institute is going to be unique and going to make an impact, research has to be a very strong part of that," Paul said.

Solving the Water for Food Equation

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Speakers

President's Welcome

James B. Milliken
President, University of Nebraska

The Robert B. Daugherty Water for Food Institute (DWFI) conference has quickly, and for good reason, earned a reputation as one of the world's best forums to address global food security in an increasingly populated world, James B. Milliken said. "Key opinion leaders, researchers, industry leaders and policymakers are not only on the podium or panels today, they are all around you. This is an opportunity for many of us to meet with colleagues from around the world in what is a truly global conference and learn from each other."

The Robert B. Daugherty Charitable Foundation and the University of Nebraska (NU) envisioned DWFI as an opportunity for leaders, governments, higher education, industry and water-focused organizations to work together to identify issues, build partnerships and seek solutions. In keeping with Robert Daugherty's philosophy, the institute will seek practical solutions to real-world problems.

The Daugherty Foundation's founding gift enabled DWFI to progress quickly. "We are very, very grateful for their investment, their support, their confidence in the University of Nebraska," Milliken said.

The key to success is leadership. In February 2012, Roberto Lenton joined the DWFI as the founding executive director. His extensive experience in water management, food security, sustainable agriculture and responsible use of resources makes him the ideal person to establish

James B. Milliken

the Daugherty Institute as a global leader in research, education and policies related to water for food.

Early on, DWFI focused on building international partnerships. Over the past three years, the institute has developed relationships with governments as well as educational, industrial and water-related organizations. NU faculty also have benefited

"This is an opportunity for many of us to meet with colleagues from around the world in what is a truly global conference and learn from each other."

from new, expanded partnerships in water management, crop productivity, yield gap analysis and related fields.

"The results of these efforts are exciting," Milliken said. For example, DWFI signed a joint educational agreement with UNESCO-IHE in Delft, the Netherlands, that allows NU and IHE students to participate in exchange programs. Nineteen students recently arrived from the Netherlands to attend the first course offered through this partnership. In 2013, DWFI and IHE will launch a joint master's degree program in water for food as well as additional short courses and collaborative research projects.

DWFI also began collaborating with USAID to expand research and development capabilities related to water management in the Middle East and North Africa. "This work will leverage our strengths in irrigation, groundwater management, rainfed agriculture and drought risk assessment, critical areas in the quest for food security," Milliken said. "It is important work that will have implications in many developing nations."

A partnership with Jain Irrigation Systems Ltd. of India will focus on enhancing water productivity through water policy education, human capital development and other joint undertakings. "I envision a series of projects where we are able to focus on practical solutions," he said.

Additional promising partnerships are being developed with organizations in Brazil, China and elsewhere. The institute also co-hosts and participates in global conferences and recently hosted a lecture in agriculture and food security by M.S. Swaminathan, World Food Prize laureate and father of the Green Revolution in India.

Education plays a fundamental role, Milliken said. The institute continues to expand relationships globally and to look for additional opportunities for student exchanges, fellowships and educational programs. "I think that we have a responsibility for educating the next generation of not only scientists, but policymakers and industry leaders and citizens so that we can play some small part in helping the population better understand the use of this important resource and to inform science-based policy decisions that help us achieve our goals."

Speakers

The Future of Water for Food: Addressing the Challenge

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

"The issues that we are discussing are very technical in some ways … but the backdrop is that the issues of water for food essentially transcend so much of what is driving the world today," Roberto Lenton said. In Nebraska, the political significance of water has long been understood, demonstrated by water use disputes in the Republican River Basin. Less recognized are the land and water conflicts at the root of many of today's headlines, such as Arab Spring and the fighting in Darfur, Sudan. "I think we have to recognize that the issues that we deal with manifest themselves in these larger political arenas that govern so much of where we are today and where we will be heading."

Roberto Lenton

Lenton described the trends in global food and water demands and what is needed from those working in the field to overcome the challenges ahead. He also outlined the vision and potential of the Robert B. Daugherty Water for Food Institute (DWFI) in meeting those needs.

Water for Food Equation

Trends in both global food demand and the water available for food production – two sides of the water for food equation – are pointing in the same worrisome direction: the need to grow more food with less water, Lenton said.

Population growth clearly drives both trends. Because most growth is in areas that have long suffered from poverty, as these regions gain wealth, increasing consumption and changing diets will add additional demands on resources. Increasing urbanization also plays an enormous role. Nearly 150 cities in South and Southeast Asia have more than 1 million inhabitants and continue to grow astronomically. These megacities create tremendous consequences for drinking water, industry and other water users.

Climate change also affects the water equation. In addition to reduced precipitation and increasing

variability, the steps taken to mitigate climate change, such as biofuel production, also affect water resources and food production.

While global trends point to the need for more food with less water, Lenton cautioned that regional issues are heavily influenced by local physical and institutional conditions, which vary worldwide. "The problems and the solutions will differ from case to case, and that's simply something that we have to be aware of when we're dealing with the water for food equation," he said. "Cookie-cutter approaches simply don't work."

Additionally, the water for food equation manifests differently at different scales, from the household to the global, yet most people's primary concerns are on one level. At the farm scale, for example, producers think about maximizing yield while reducing water use to save money. At a national scale, policymakers seek a broader perspective of ensuring food security while minimizing agricultural water allocations to maintain water availability for other needs, such as energy production, industry or environmental sustainability. At the global level, feeding the world with limited freshwater resources involves trade issues: using water where it's available to feed those living elsewhere. People working at different scales must interact to understand each other's viewpoints and struggles, Lenton said, citing the global Water for Food Conference as an important forum for those conversations. "In the end, you can't really solve the global issue if you don't understand what's happening at other levels."

Crossing Disciplinary Scales

Interdisciplinary work gives the ability to cross these scales. Lenton used Nebraska to illustrate this challenge and highlight the potential benefits of interdisciplinary efforts. In the past few decades, Nebraska's irrigated agriculture has ballooned to 4 million hectares (9.8 million acres), more than any country in the Americas, aside from Mexico. Therefore, the state's level of irrigation is considerable even by global standards.

"You can't really solve the global issue if you don't understand what's happening at other levels."

Although Nebraska farmers long ago adopted efficient irrigation technologies, Suat Irmak, University of Nebraska–Lincoln (UNL) agricultural engineer and interim director of the Nebraska Water Center, formed the Nebraska Agricultural Water Management Network, an alliance of farmers and researchers working to help farmers reduce water and energy consumption. Participating farmers are given devices to measure soil moisture, enabling them to apply water as needed, instead of automatically. The network now represents 500,000 acres (202,342 hectares), and participants collectively save 300 million cubic meters of water each growing season.

At an even larger scale, Nebraska's watersheds provide another opportunity to save water through surface and groundwater management. Forty years ago, Nebraska pioneered the establishment of Natural Resources Districts (NRDs), 23 entities governed at the watershed level. Locally elected boards of directors have taxation authority, providing NRDs with budgets and staff to manage resources, which vary greatly across the state.

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The history of the Upper Big Blue NRD demonstrates the benefits of managing at watershed levels, Lenton said. In the late 1970s, the NRD faced a dwindling water table. At that time, officials established groundwater regulations to encourage water conservation and to maintain the water table for the long term. Although irrigation has increased four-fold since then, the regulations led to more careful water use. Today the groundwater table is actually higher than it was in the '70s and is no longer threatened by overexploitation from agricultural use. Though not all Nebraska watersheds are better off now than in the 1970s, Lenton argued that "the overall news is a positive picture compared to what you'll find in other parts of the U.S., and certainly with what you find in other parts of the world. There's much to be learned there."

In another example, in the 1970s a highly damaged watershed was silting a downstream lake in Sukhomajri, India, located in the pre-Himalayan hills north of Delhi. After urban residents complained, a small check dam was built upstream, creating a small reservoir. Local villagers recognized that the dam provided a stable water source for converting highly unstable rainfed crop systems to irrigation. They established a system for distributing the water equitably among villages, and household incomes in the poor area increased dramatically. Guaranteeing their incomes also provided an incentive for the villages to maintain the check dam and, more importantly, to conserve water. The system created other water pressures, however. Because the check dam led to rising groundwater tables, farmers began building tube wells to irrigate rather than participating in the dam system.

Nevertheless, Lenton emphasized that the initiative, critical to farmers' livelihoods, was driven by outside pressure. By solving the downstream problem, the solution gained its own momentum as people recognized the benefits.

Vision of the Daugherty Institute

The institute's vision and activities will provide opportunities for people working at all scales of the water for food equation to come together and find innovative solutions, Lenton said. Nebraska, an important national and global food producer that manages major river systems and aquifers, has a track record of innovation led by farmers, NRDs and state agencies. That experience allows the Daugherty Institute to build on significant experience in water research and management.

The University of Nebraska (NU) also has a long track record of engaging in water for food issues at the state and, increasingly, global levels. Its strong commitment to interdisciplinary efforts spans not just hydrology and agricultural sciences, but also social sciences, informational sciences and public health. Importantly, NU also brings together research and practice.

> *"Cookie-cutter approaches simply don't work."*

Lenton said DWFI is envisioned as a three-legged stool of research, education and policy advice. "The three are absolutely fundamental, and it's the combination of the three that will make this institute really add value," he said, adding that its focus is the efficient and effective use of water, as well as sustainability, and includes both rainfed and irrigated agriculture.

Republican River, Nebraska

DWFI is distributed across the four NU campuses to all relevant departments and programs and is tied together under the overarching theme of "more food with less water" – a theme intended to span all spatial scales and contexts, from Nebraska to the world. To overcome the challenges of interdisciplinary research, the institute is implementing joint projects that bring people together around this common theme, both within the university and through outside collaborations.

Lenton concluded with an example that crystallizes the institute's potential. The Global Yield Gap and Water Productivity Atlas, spearheaded by UNL agronomist Ken Cassman, will produce a publicly available, comprehensive atlas that maps attainable yield potential for every region on Earth. The hugely ambitious project encompasses different scales, from farm to global, and emphasizes the need for research to support evidence-based policymaking. "It's a very good example of what we hope this institute stands for and what we hope we can contribute through this exciting new venture."

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The Future of Agriculture: A Look Through the Green-Blue Water Lens

Malin Falkenmark
Senior Scientific Adviser, Stockholm International Water Institute, Sweden

Malin Falkenmark described recent studies conducted by the Stockholm International Water Institute (SIWI) investigating food security and the future of agriculture through the lens of blue and green water flows.

Blue and Green Water

Rainfall becomes either blue water, liquid that travels as surface water or groundwater, or green water, vapor that returns to the atmosphere. On land, water either joins blue water flow as surface runoff or evaporates as green water flow.

Malin Falkenmark

Rainfall that infiltrates the soil can become groundwater or is picked up by roots and returns to the atmosphere, transpired by plants as green water.

Incorporating green water into a country's water balance can completely alter its water picture, Falkenmark said. For example, Kenya appears to have little water, as blue water resources account for just 5 percent of its entire water balance. Another 95 percent of Kenya's water returns to the atmosphere as green water flow from evaporation and transpiration from grasses, forests and crop production.

Countries' green and blue water flows vary greatly. Comparing water balances among a temperate boreal forest, a semi-arid tropical savanna and a humid tropical rainforest demonstrates these differences. Temperate zones have limited precipitation, about 600 millimeters annually, and moderate evaporation of between 100 millimeters and 500 millimeters yearly. There, about half of the rainfall returns to the atmosphere as green water flow and the rest forms blue water runoff.

In semi-arid tropical savannas such as Kenya, the annual rainfall is similar, but evaporation can reach up to 2,000 millimeters yearly. Because nearly all precipitation returns to the atmosphere with less than 100 millimeters remaining as blue water, small rivers contain water only during rainstorms. Most of the world's poor and

undernourished people live in semi-arid tropical savannas. In contrast, humid tropical rainforests have the same high evaporative demand as semi-arid tropics, but the enormous amounts of rainfall they receive meet surface water demands and supply large rivers, such as the Amazon and the Congo.

Feeding Humanity by 2050

In the past five years, SIWI has conducted studies on feeding humanity by 2050. In one recent study, the institute predicted total blue and green water availability by country in 2050. The study divided countries into four categories based on whether they require at least an annual 1,300 cubic meters of blue and green freshwater per person to grow enough food for their population, and whether countries with less than an annual 1,000 cubic meters per capita of available blue water suffer chronic water shortages. Countries with sufficient blue and green water are projected to represent 19 percent of the world population in 2050. Countries with too little blue water, but sufficient green water to develop rainfed agriculture, will represent 14 percent of the 2050 world population. Those countries with too little green water, but sufficient blue water to support irrigation, will represent about 21 percent of the world's population. Finally, countries with too little blue or green water to support either rainfed or irrigated agriculture are projected to represent 46 percent of the world's population by 2050. These water-short countries must look to converting terrestrial ecosystems into cropland, importing food and radically increasing water productivity, Falkenmark said.

Upgrading rainfed agriculture, even in countries with sufficient green water, will be challenging. In a three-year study of a semi-arid Nigerian farm, 90 percent of water was received as rainfall, but only 12 percent reached the farmer's crops, reducing the potential yield of 7 tons per hectare to just 1 ton. The farm lost a third of the rainwater to surface runoff and a fourth went to groundwater due to poor water-holding capacity. Of the green water that stayed in the root zone, 70 percent evaporated from wet surfaces; the roots, damaged by repeated dry spells, were unable to absorb water.

Agriculture uses tremendous amounts of water, but water requirements for food production also depend greatly on people's diets. The world is heading toward a daily average diet of 3,000 kilocalories per person with 20 percent coming from animal protein. At current productivity levels, that amount of consumption requires 3,500 liters of water per day, 70 times more than is needed to meet urban household requirements. Narrowing the yield productivity gap 25 percent would reduce that quotient from 70 percent to 55 percent, but even then, water is insufficient to maintain that level of consumption, Falkenmark said.

However, maintaining realistic dietary expectations for caloric and meat consumption and reducing the agricultural yield gap would cut water requirements significantly. SIWI demonstrated that consuming 5 percent of kilocalories from animal protein would require 2,100 cubic meters per capita of water annually and allow water-short countries to just meet food needs. Simultaneously reducing caloric consumption to 2,200 kilocalories daily would further decrease dietary water needs to 800 cubic meters, providing a global water surplus. Notably, however, no low-income country will have a water surplus under any scenario, and therefore none will be able to

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support their populations by 2050, Falkenmark said. "Food is, of course, not the only biomass water claimant. Because, in addition to that, we need to grow cotton, fuelwood, and we also need to take and pay attention to the carbon sequestration needs. There are plenty of research items for the future to address."

Global Scale Observations

Disturbances in water flow diversions among the atmosphere, land and water are causing major environmental problems, Falkenmark said. Desertification, linked to the surface-level blue and green water partitioning point, is an infiltration problem in which most of the rain runs off as blue water, reducing the opportunity to produce green water. Salinization, on the other hand, takes place at the partitioning point below ground when deforestation reduces green water uptake, increasing blue water percolation and groundwater recharging. If the soils contain salt, as groundwater levels climb, the resulting saltwater rises toward the surface. This is occurring in southwestern Australia. Savanization results when rainforest deforestation reduces green water flow back to the atmosphere, thus decreasing rainfall, as is happening in South America's La Plata River Basin located downwind of the Amazon rainforest. The monsoon shift over India is caused by a similar vapor flux disturbance, but some hypothesize that increased vapor from irrigation is increasing rainfall.

Another major concern is groundwater and river depletion. Agriculture consumes rainfall, either directly through consumptive use that returns water to the atmosphere or indirectly by taking runoff water as irrigation. The more rainfall agriculture consumes, the less runoff is generated, on which society depends to meet other needs. The remaining runoff is environmental flow that feeds aquatic ecosystems and is fundamental for the health of aquatic ecosystems and fish production. Expanding agricultural production reduces water in the rivers and puts aquatic ecosystems at risk. The concern is that river depletion is going too far, Falkenmark said.

To secure environmental flow, consumptive use for agricultural production and other societal needs would have to be limited. The planetary freshwater constraint is formulated as the maximum acceptable consumptive blue water use, which must remain below 5,000 cubic kilometers per year. Agriculture has already appropriated 2,600 cubic kilometers, leaving a window of 2,400 cubic kilometers. Under current dietary tendencies of 3,000 daily kilocalories per person with 20 percent from meat, agriculture will require an additional 1,700 cubic kilometers by 2050, leaving just 700 cubic kilometers for biofuel, carbon sequestration and other needs.

By 2050, 1.5 billion people will live in water-deficient regions without purchasing power, the hot spots of tomorrow. Falkenmark concluded by highlighting three emerging core questions. First, given the enormous number of people who will be living in water-deficient countries and the high dependence on virtual water, how can the water trade be made reliable? Second, what is the future for these water-deficient and poor countries, and how can their food security be achieved? Economic development must not be based on water, she said. And third is the question of how to balance competing needs between biomass production and realistic dietary expectations within the planetary freshwater constraints.

Water and Food Security: Stumbling Toward Malthusian Oblivion or Pioneering Cornucopia?

Colin Chartres
Director General, International Water Management Institute, Sri Lanka

The International Water Management Institute (IWMI) was established in Sri Lanka by the Ford Foundation and others in the mid-1980s. Today, IWMI works in about 20 countries. Colin Chartres reflected on the history of IWMI's work and described important studies that have advanced the understanding of water and food.

Colin Chartres

Growing Awareness

Water scarcity used to receive little attention because of optimism surrounding new land and water resource development, Chartres said. Not until the 1990s and 2000s did people consider the possibility that too little water exists to produce the food necessary, particularly given a global shift toward diets higher in calories and meat. Today, water scarcity is a major concern.

The same cannot be said for food. Food shortages have been infrequent since the Green Revolution when new high-yielding varieties doubled cereal production and irrigation expanded, initially through World Bank lending and later through private investment. As a consequence, the world food price index declined significantly until it began rising sharply in about 2008. A continued rise is speculative, but the trend is worrisome, Chartres said.

Of equal concern is the living planet index of freshwater species, which continues to decline as irrigation removes more blue water from rivers, lakes and other systems and as the remaining water becomes contaminated. "I think one of the great challenges of the future … is really looking at whether or not we can sustainably intensify agriculture in harmony with the environment," he said.

IWMI History

IWMI initially worked on participatory irrigation management (PIM) and the development of water user associations. PIM, now a model for irrigation management worldwide, hasn't always succeeded in the developing world. Data show as many failures as successes. Accepting that PIM is a good model for managing water, future studies should investigate why failures occur, he said,

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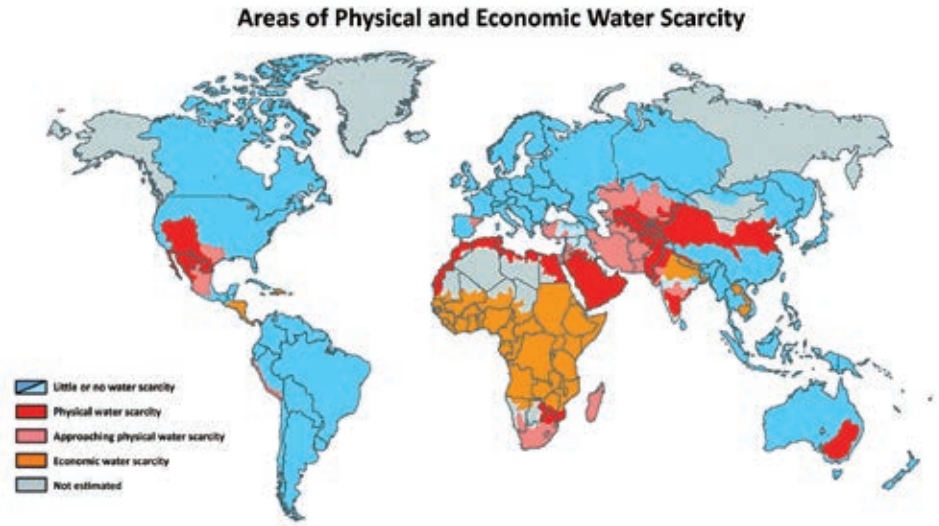

Source: International Water Management Institute

suggesting setbacks may relate to investment issues in capital or infrastructure, capacity building or other institutional problems.

As IWMI evolved, it began looking at hydrology from a river basin perspective, and the concept of integrated water resource management gradually emerged at IWMI and worldwide. Although the concept dates to the 1930s, even today most water is managed with little overall governmental integration. Nevertheless, IWMI's work highlighted that many water basins no longer flow to the ocean because of over-extraction. Environmental water requirements also go unmet in a substantial swath of subtropical countries from North Africa through the Middle East, as well as parts of the U.S., Mexico, Australia and elsewhere.

Having recognized this problem, researchers began studying the movement of both blue and green water. Water accounting is a complex task, made more difficult because people dislike sharing data, said Chartres, who helped establish water information systems in Australia's Bureau of Meteorology. But sharing data is vital, particularly considering that major rivers and their tributaries flow through multiple countries, and water accounting must receive more attention.

More recently, IWMI studied gaps between water supply and demand. Unless major climate change occurs, supply will remain relatively constant, but demand for water will continue rising. Using India as an example, McKinsey & Company projects the country's water supply to remain at 744 billion cubic meters in 2030. Assuming 2.8 percent growth in water usage, India's aggregate demand will double to nearly 1,500 billion cubic meters, creating a 50 percent overall water deficit. Some regions will be worse off than others. Consequently, India faces expensive national river-linking programs to move water to areas with greater needs. "I think the real question we have to ask ourselves in all our environments is: Are there cheaper ways of doing this? Do we need to go into these massive engineering solutions where we're not picking the low-hanging fruit in terms of doing much better with the existing water though efficiency and productivity gains?" Chartres asked.

"I think one of the great challenges of the future … is really looking at whether or not we can sustainably intensify agriculture in harmony with the environment."

In the last dozen years, IWMI also has studied wastewater reuse, focusing on partially treated or untreated wastewater, which typically goes to urban vegetable production in the developing world, despite the health risks. About 700 million people rely on vegetables grown under wastewater reuse systems. The institute is working with the World Health Organization and local authorities in places like Ghana, Sri Lanka and India to ensure that water is used with greater consideration for safety, from the field to the plate.

Most recently, IWMI's 2007 Comprehensive Assessment demonstrated that many countries, particularly in Sub-Saharan Africa, were economically water scarce because they had insufficient funds to invest in developing water resources for urban, domestic or irrigated agricultural purposes. If business continues as usual, global green and blue water demand will rise from about 7,000 cubic kilometers today to about 13,000 cubic kilometers by 2050, a level that may not be possible and wouldn't be sustainable, Chartres said.

The World in 2050

Over the next 20 years, greater water scarcity – driven by population growth, more biofuel production, higher meat diets and increasing urban demands – will fundamentally affect food security, poverty reduction and the environment. Gross domestic product also plays a significant role because even as population growth declines by 2050, many people in the developing world will gain wealth. "Those kinds of drivers, dietary change and so on, paint a pessimistic picture even without climate change," Chartres said. The Food and Agriculture Organization of the United Nations (FAO) predicts that food production must increase by 70 percent, yet climate change may reduce yields in Sub-Saharan Africa by 30 percent.

IWMI used the Water, Agriculture, Technology, Environment and Resources Simulation Model (WATERSIM) to research future scenarios, with and without enhanced trade. The model predicts that by 2050, following a business-as-usual scenario (50 percent population growth and 365 percent gross domestic product growth), demand for all major staple crops will grow between 20 and 80 percent, depending on the crop; notably, poultry demand will increase 83 percent as people consume more meat. The model also assumes price changes, such as a 228 percent rise in potato prices by 2050. Even under an optimistic scenario of less population growth and higher GDPs in Asia and Africa, the model predicts blue water demand will increase 50 percent to 6,000 cubic kilometers. Agricultural water demand will stay relatively constant, but demand from urban and industrial users will increase dramatically. Agriculturalists have questioned this prediction, Chartres said, but the model assumes, as reality suggests, that water is given first to domestic users, then to industry and finally to agriculture. Environmental water also is needed.

The blue water supply can sustain about a 15 percent increase. Therefore, global demand will

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exceed supply by 2040, even with enhanced international trade. However, slightly increasing green water productivity allows agriculture to meet food requirements. Nevertheless, without enhancing trade, demands on land and green water remain higher.

Climate change also must be factored into discussions about agriculture, Chartres said. Using Intergovernmental Panel on Climate Change scenarios, IWMI has studied changes in global rainfall, temperature and potential evapotranspiration. Though specifics are difficult to predict, climate change will cause more droughts, later-onset monsoons and greater variability. The WATERSIM model predicts water demand could increase up to 17 percent due to rising evapotranspiration from warmer temperatures.

Given these studies, Chartres raised the global paradox: how to feed 2 billion more people using the same or less water in an era of climate change. He offered several solutions:

- **Reduce waste.** This is a critical area that must be addressed at the production level, particularly issues of inadequate storage, transport and market access in the developing world and at the point of consumption. Nearly 180 kilograms per capita of food were discarded in the European Union in 2010.
- **Encourage trade.** The best outcomes rely on improving trade. Trade already drives geopolitics, manifested, for example, as land grabs in water-scarce countries working toward future food security.
- **Increase productivity.** China has dramatically improved productivity without increasing land area, but Africa's increasing yield comes from expanding agricultural land, an unsustainable solution.
- **Encourage healthier diets.** The average daily diet in wealthier countries is 2,800 kilocalories, with 224 grams of meat per person. Worldwide, consumption is expected to rise tremendously by 2050. Following the recommended healthy daily diet of 2,000 kilocalories and significantly less meat consumption, combined with a 50 percent reduction in other waste, would save an enormous 1,350 cubic kilometers of water, Chartres said. Agriculturalists can't do it all; public educational campaigns are needed.

Ultimately, saving water requires: prioritizing political understanding and leadership; using a nexus approach in which water is viewed in terms of its relationship with food, energy and the environment; implementing new policies that protect the environment and minimize energy use and carbon emissions; reforming existing governance and institutional structures; enforcing regulations; and instituting education and capacity building at all levels. With significant changes, productivity gains can limit water demand to roughly 9,000 cubic kilometers. Factoring in food waste savings would curb water demand to the 7,000 cubic kilometers used today.

A positive outcome is achievable but much effort will be required to get there, Chartres said. "We've got to do this in harmony with the environment. We can't just go on exploiting the environment because everyone is beginning to realize the importance of environmental services, particularly with freshwater, for fishery, habitat, for biodiversity, aesthetics and so on."

Working Together for Water: Collective Action and Property Rights

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

Ruth Meinzen-Dick described water management problems and successes in the context of the water commons and the importance of institutions.

"Technologies alone do not solve the problems," she said. "Government policies alone do not solve the problems. What we really have to get is working together."


Ruth Meinzen-Dick

The Water Commons

Water is an important commons because it connects people, Meinzen-Dick said. A farmer may work independently for one growing season, but over longer time spans or across groups of farmers, communities and nations – or even globally – water becomes a form of commons. For example, without tenure security or property rights, a farmer doesn't have the incentive, or perhaps the authority, to make long-term commitments, such as installing drip irrigation.

Sharing new technologies or information about water management practices is another example of the commons, because such sharing requires coordination with others. Technology as a commons varies depending on farm sizes and turnaround time on investments. In Nebraska, a center pivot irrigation system may service a portion of one farm, but in Zimbabwe, a single system may encompass many farms, requiring coordination among farmers. At even larger scales of time or space, including watershed management, canal irrigation, reservoirs and transboundary river basins, water commons require greater coordination.

Despite reports of the inevitable tragedy of the commons, Elinor Ostrom, Nobel Prize winner in economics, and other scholars cite examples of successful commons, some that have existed for a millennium. But coordination doesn't happen automatically, and many attempts have failed. In general, governments have an advantage at high levels, but at lower levels, collective action among people directly affected by the commons becomes more significant. Interactions between the state and collective actors also are important, and many irrigation management transfers have failed because of improper coordination.

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Cassava leaves

More than just formal group membership, collective action requires getting people to work together. It's defined as action taken by a group, either directly or on behalf of the group's shared interests, such as forming and enforcing rules on water use.

Ostrom developed eight broad design principles that long-enduring commons share, many of which she developed from studying water commons. These principles aren't rigid rules or a panacea in all situations, Meinzen-Dick said, but they often are effective in managing commons, especially water. The eight principles are:

1. Clearly defined boundaries, of both users and resources.
2. Congruence. The rule system must fit local conditions and a balance must exist between contributions and benefits. In many irrigation systems, problems result when rules require farmers to contribute more than the economic benefits they receive.
3. Collective choice arrangements. People should participate in creating rules so not all rules are set and enforced by outsiders.
4. Monitoring users and resources. A mechanism for monitoring users ensures they follow the rules and builds trust that others are obeying as well. Monitoring resources helps to determine their availability and identifies the need to adapt to current conditions.
5. Graduated sanctions. People don't like enforcing punishments viewed as too harsh, but if sanctions are set too low, they ignore rules. People are more likely to enforce rules if graduated sanctions give neighbors an opportunity to comply.
6. Conflict resolution mechanisms. Without a system to resolve problems, people who feel aggrieved may break more rules, or conflicts between groups may lead to the system collapsing.

7. Minimal recognition of the right to organize. Some societies prohibit people from organizing themselves under a set of rules, which undermines collective action and resource management.
8. Nested enterprises in which a series of organizations is formed, each with defined roles and representation at other levels. For example, an irrigation canal that serves thousands may establish a system in which users at the water-course level form an organization but have representation at the next level up and so on. Each level interacts with different government agents in what Ostrom refers to as polycentric governments.

Collective Action

Years ago, Karl Wittfogel advocated the state's involvement in water management. Yet studies demonstrated that many farmer-managed irrigation systems outperformed government-run systems. As a result, a movement began to transfer management of poorly performing canal systems to water user associations. By the time governments were willing to transfer management, the canal systems often were dilapidated, and irrigation no longer paid well, so governments refused to subsidize them. Not surprisingly, transferring a decrepit government-run system to farmers didn't result in high-quality collective action.

Many factors, like ineffective incentives or major structural obstacles, can weaken collective action, such as when two villages not used to working together are serviced by a single canal. But steps also can be taken to strengthen collective action. Many programs have hired facilitators to talk to communities or engage them in participatory planning methods or competitions designed to stimulate collective action. Policy and institutional reforms also can be initiated to encourage government agencies to work collaboratively with farmer groups. Incentives also must encourage groups to work together and empower them to manage resources, which means allowing them to set some rules.

Empowering people also involves property rights, both to water and the infrastructure. Often governments transfer management responsibilities but not rights, such as the authority to set and enforce rules, which creates major problems, Meinzen-Dick said.

Property rights may not involve ownership, but may reflect user rights, such as recognition that a claim is legitimate based on state or other type of law. Rights are divided into hierarchical bundles, each providing different incentives. User rights involve access to the resource, withdrawal from the resource and exploitation of the resource in some way. Other rights involve control or decision-making: management rights, such as changing the water flows by adding a canal or closing a gate; exclusion rights to keep others from using the water; and alienation rights to sell or transfer resource rights. With water, rarely does one person or group have all the rights, Meinzen-Dick said.

> *"Technologies alone do not solve the problems," she said. "Government policies alone do not solve the problems. What we really have to get is working together."*

Rights can come from various sources, like state law or regulations specific to a project. Customary law also can be important. A development project

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that disregards a right embodied by customary law may be resented or its rules ignored. Similarly, religious laws or social norms may be relevant. Each type of law often interacts with others, creating a dynamic situation in which people may appeal to different views about rights to water or infrastructure.

When asked about the difference between collective action and water markets, Meinzen-Dick said that coordination can be done by the government, collective action or markets. For example, in the 1970s and 1980s in Pakistan, large government-run tube wells serving multiple households were widely considered disastrous because of high costs and poor service. When smaller pumps became affordable, many farmers invested in them. One well still served multiple farms, so either one farmer would invest in a well and sell the extra water, or a group of farmers would purchase and operate a well together.

Transferring water within a market requires a physical infrastructure. The Pakistani wells were localized, and the country established the infrastructure to enable water transfers, but not all situations have that flexibility, she said. The Pakistani water markets increased availability to small farmers, but when water became scarce, smaller, younger or lower-status farmers were likely to go without because richer and more senior farmers had the right to buy water. With collective tube wells, smaller farmers were more likely to have water during scarcity. However, collective action may have higher transaction costs. "Right now my hunch is that when a lot of technology and mechanical technology is involved, then the water markets are more likely to be a coordination mechanism," Meinzen-Dick said.

Success Stories

Meinzen-Dick shared several examples of successful collective action. She cited as a small-scale example her work with the World Agroforestry Center to protect springs in Kenya's Nyando Basin where many communities lack safe sources of drinking water. Women benefited most because they would spend less time gathering water, but men had to pay for planting trees and laying pipes. "It was interesting to get people's interests to line up, even within households," she said.

On a larger scale, an ambitious program in Mexico in the early 1990s transferred management to water use associations and got farmers involved, successfully revitalizing thousands of hectares previously out of production due to poor management. Colin Chartres offered an additional example from Australia's Murrumbidgee River irrigation system, which was declining rapidly due to salinization and other problems. Land reform and better management of salinity and drainage rejuvenated the system, which is now highly profitable.

But Meinzen-Dick warned that no magic bullet exists. "There's a real hunger for success stories that are simple. I've lived through a lot of these different panaceas, and when you transfer that model to another place, it might not be sustained over time. There's not just a simple solution."

System and Crop-Level Drivers of Grain Production in Rainfed Agriculture

Victor Sadras
Associate Professor, Principal Scientist, Crop Ecophysiology,
South Australian Research and Development Institute

Production systems are sustainable if they're profitable, ensure safety and meet environmental and social expectations, Victor Sadras said. A disturbance to any of these components affects the others. "We are what we are for many reasons, but one of them is how we relate to the landscape," he said. Landscape disturbances, such as those that result from climate change, affect both individuals and entire communities. Australia, for example, is recovering from one of the worst droughts on record, which has led to financial problems as well as family breakdown and mental illness.

Victor Sadras

But global warming also has positive aspects. In a few decades, warming will lengthen the growing season in Finland and other northern countries, thus doubling food production. Adapting agricultural techniques to capture more light energy, made possible by an increase in the portion of the year in which crops are grown, could be the most rewarding change made to increase food supplies, he said.

In the context of sustainability, a researcher's role involves science, technology, education and policy. To ensure relevant findings, researchers must recognize that production improvement depends on better agronomy and better varieties, as well as the synergy between them. Semi-dwarf trees were useless, for example, until technology advanced to control grass weeds. To contribute to productivity, sciences such as crop physiology, climatology and soil science must engage meaningfully with agronomy and breeding, Sadras said.

Sadras discussed yield and its resources from both the system and crop perspective and offered new ways of viewing yield that will lead to increasing production.

System-level Yield Resources

Before the advent of agriculture, survival depended on the ratio of energy obtained from food relative to energy spent chasing food. In the Neolithic Age, humans began growing crops,

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feeding themselves during the winter and keeping some seed for the next crop. This practice led to the early definition of yield: grain per grain, or a plant's capacity to multiply grain. For example, a single corn plant yields 300 grains on a cob. This long-held definition favored tall, aggressive plants with large heads and small grains.

As land became limited, the definition of yield shifted from grain per grain to kilos per hectare. "We're heading to a measure of yield where the time dimension is made explicit," Sadras said. "In many systems, growers are not motivated to get high yield for a single crop but to feed many crops per unit of time." This change results in a trade-off from the production of individual crops to system production.

In southeastern Australia, low fertility soils receive about 400 millimeters of rainfall annually, with 65 percent occurring during the autumn to spring growing season, which limits crop choices.

Fifty years of data show Australian yields of wheat, the primary crop, have increased over time. Many breeding changes account for the increase, including reduction of plants' competitive ability. Yield can't be selected by growing an isolated plant, and modern varieties are more reliant on weed management. "High yield per crop goes against high yield per plant," Sadras said.

A second modern trade-off is found in single versus double cropping. Double cropping is widespread, even though improvement rates in soybean yields in single-crop systems are much higher than in double-cropping systems. In double cropping, the grower sacrifices soybean yield to have two crops in a season. In some cases, examining kilos per hectare results in a biased view.

Crops require carbon dioxide, radiation, water and nutrients. An important difference between the water and radiation requirements is that

Soybean harvest

rainfall can be efficiently stored for later use, while sun energy not used today cannot be stored and is lost forever. "That's a fundamental aspect of technology and food production," Sadras said. "How do we harness that sunlight?"

Studies show that when growing wheat, some water and most photosynthetically active radiation are lost during the year. A producer cannot do much to improve the crop. Growing soybeans after a wheat rotation, however, dramatically increases the system's capacity to capture radiation and water. The 30 to 40 percent annual rainfall captured by a single crop increases to about 70 percent when two crops are grown sequentially. Wheat yield is unaffected by double cropping, but soybean yields are reduced 40 percent relative to timely sown soybean crops because of dry soils and the delay in sowing time to accommodate wheat. Nevertheless, the overall productivity of double cropping is 60 percent greater than that of a single crop. In addition, because fixed costs also are less, overall profits in a double-cropping system are much greater than in less intensive cropping systems. Double cropping also returns more carbon to the soil as stubble.

In rainfed agriculture, risk management is critical. Excessively dry seasons reduce productivity and increase financial risk. The innovative company El Tejar manages risk at the continental scale, by challenging the view that growing crops requires owning land and machinery. It has aggressively leased land, outsourced farm operations and recruited skilled scientists and technologists. The company grows crops in multiple areas, so low yields in one area are buffered by better yields in another. "The unit for risk management is not the farm. It's a region," Sadras said. "That's a huge innovation, I think."

Crop-level Yield Resources

If a crop yields less than is possible with the amount of water available, what is the source of the gap? Sadras asked. In southeastern Australia, evidence suggests that much of the gap is due to nitrogen deficiency from poor soils and low nitrogen use. Modeling shows high nitrogen use eliminates the yield gap. But growers don't use more nitrogen due to low rainfall risks. "That's one of the paradoxes in this system," he said. "(It's a) very dry system, but at the end of the season, we have water left in the soil if there wasn't enough nitrogen to capture that water."

One perspective of this water-nitrogen equation is the view that natural selection favors physiological co-limitation. In the Australian system, studies show that a high degree of water and nitrogen co-limitation favors wheat yield in these environments. Independent studies in Spain demonstrated similar results.

Another perspective focuses on efficiencies. A nitrogen-deficient crop will have low water use efficiency for two reasons. First, the biomass produced per unit transpiration could be low, which is consistent regardless of crop species, climate or soil. It's hardwired into the crop's biology: the plant needs nitrogen to yield a high biomass per unit transpiration. A second reason is high water loss through evaporation.

Obtaining high water use efficiency means a lower yield return for that additional nitrogen. Therefore, a trade-off exists between water use and nitrogen use efficiencies: nitrogen is required for high water use efficiency, but nitrogen use efficiency drops. This, too, is hardwired into crops. Except for legumes, that quality is universal, regardless of soil and climate, rainfed or irrigated, Sadras said.

Speakers

"Production gains of 20 to 40 percent are possible by rearranging crops in space and time, and is perhaps the area where the greatest gains can be made."

Growers can achieve, for example, 20 kilos of grain per hectare for each millimeter of water, but that would require 250 units of nitrogen, an unrealistic amount given the risk of drought. Instead, growers operate at between 10 kilos and 15 kilos of grain per hectare per millimeter. "When you look at that, it makes a lot of sense," Sadras said. "What they're doing is sacrificing water use efficiency but achieving the maximum return for the dollar invested in nitrogen." This gap between actual yield and the obtainable yield per unit of water use provides an opportunity to increase both yield and water use efficiency.

This new perspective of water and nitrogen changes the interpretation of producers' decisions, he said. Growers aren't inefficient; they have found a good solution to this trade-off under these conditions. This trade-off is important to consider in other countries with chronically deficient nutrients, including many areas in Africa.

James Specht of the University of Nebraska–Lincoln commented that Sub-Saharan Africa may need nitrogen as well as better varieties. Developing nitrogen use-efficient varieties allows farmers to mine the soil more without increasing production. A solution may be to provide nitrogen as well as seed to move current water productivity closer to Sadras' water boundary, he said.

Sadras said he agreed. The same paradox occurs in those areas: a very dry environment suggests that water is limited. But a range of rainfall exists, and in a year with above average rainfall, the water is wasted because no nutrients are available to capture it. Specific crop and nutrient inputs are both needed.

Rearranging crops in space and time makes production gains of 20 to 40 percent possible, Sadras said, and is perhaps the area where growers can make the greatest gains. Crop production depends on numerous storable and non-storable resources. Focusing on a single resource gives a biased view of the system, he said. Additionally, shifting the interpretation of yield gap from just water to water and nitrogen will likely be more profitable.

Water-Related Challenges to Global Food Security

Charles Iceland
Senior Associate II, World Resources Institute

Charles Iceland described the World Resources Institute's (WRI) Aqueduct project, a database and set of practical tools designed to provide detailed global water information. He demonstrated what the project shows about water risk today and into the future. "It is my hope that it will become the world's best high-resolution water risk mapping tool," he said. "I think we're well on our way toward becoming that."

Aqueduct Alliance

WRI's Aqueduct Alliance is developing an adaptable framework of indicators that will help users better understand water risk at both local and global scales. The information platform will facilitate public and private action to promote more efficient and sustainable water management. Funders include Goldman Sachs, General Electric, Skoll Global Threats Fund, Coca Cola, Bloomberg, Talisman Energy, Dow Chemical, the Dutch government, United Technologies and John Deere.

A basic water stress indicator is the ratio of total water demand to total available supply, called the water stress or water withdrawal ratio. The higher the ratio, the more water resources are stressed and the greater the likelihood of conflict between users. As of 2000, many areas already faced extremely high stress levels, greater than 80 percent,

Charles Iceland

Speakers

including the southwestern U.S., northern Mexico, much of the Middle East and North Africa, parts of southern and eastern Africa, Central Asia, northern China and most of Australia.

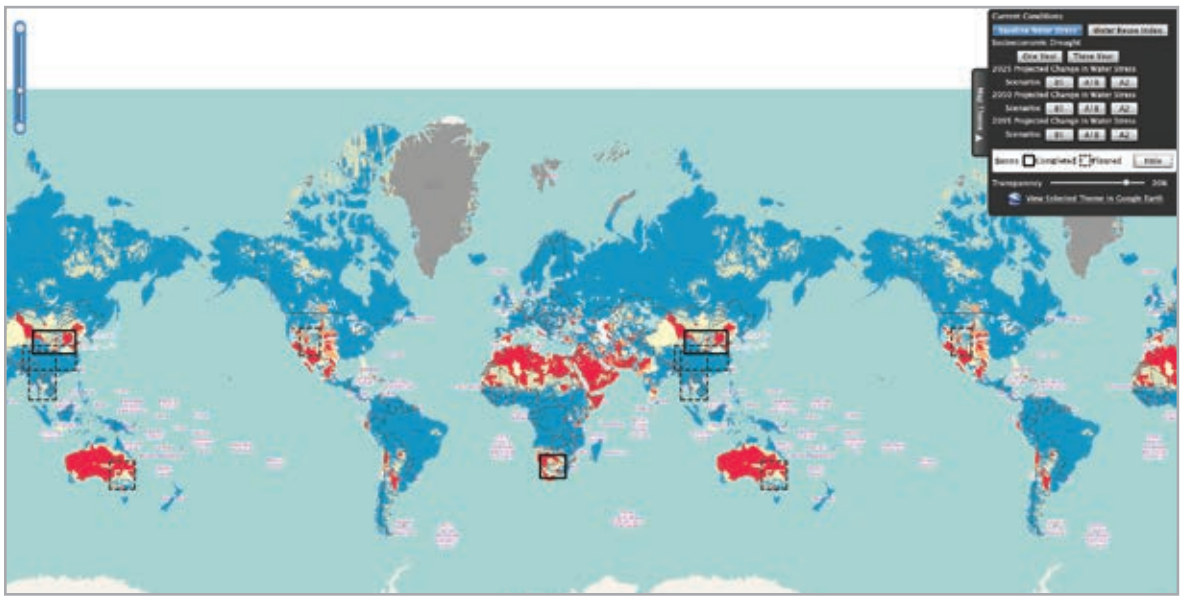
Water stress ratios will change as increasing populations and growing economies affect water demand and as climate change alters water supply. Using the Intergovernmental Panel on Climate Change's A1B scenario for 2025, water stress is expected to grow significantly. For example, northern China's water withdrawal ratio, already extremely stressed, will increase three to eight times, as will the water withdrawal ratio in the area overlying the High Plains Aquifer.

Other indicators of water risk involve water quantity, water quality and water management quality. The Aqueduct project investigated these indicators in specific basins worldwide. Some maps are publicly available through the Aqueduct Water Risk Atlas, including China's Yellow River Basin and southern Africa's Orange Senqu Basin. View the maps at http://insights.wri.org/aqueduct/atlas. Maps of Australia's Murray-Darling River Basin, China's Yangzi River Basin and Southeast Asia's Mekong River Basin are being developed.

The project also is developing a water risk news module by scanning the Internet daily for news articles related to water risk, then geocoding and embedding them into the map for users to access.

Water, Energy Nexus

The nexus between water and energy, an important competitor with agriculture for water, shows the need to adapt quickly to a swiftly changing water environment, Iceland said. Superimposing a 2010 map of the world's thermal and hydropower plants onto the global water stress map shows that 17 percent of today's power plant design capacity is located in water stress areas of 20 percent or greater. By 2025, water stress will worsen two to eight times for 29 percent of the world's power plants. Power plant operators, governments,



WRI's Aqueduct Water Risk Atlas, http://insights.wri.org/aqueduct/atlas

"My preferred solution … would be not to waste the food in the first place. And there's a shocking amount of waste."

companies and investors contemplating installing new power plant capacity will have to make major adjustments in a short time, he said.

An analogous study illustrating the water and food nexus shows that 28 percent of total global cultivated crops are located in areas of water stress. The picture is worse for irrigated agriculture, 40 percent of which is located in water stress areas. By 2025, assuming no changes in crop locations, water stress will worsen two to eight times for 49 percent of the current total global cultivated crops and for 73 percent of irrigated crops.

Regional figures are similar to global averages. For example, in both Southeast Asia and the U.S., about 40 percent of irrigated crops are located in water stress areas, and nearly three-quarters will experience two to eight times greater water stress by 2025. Although only 5 percent of Africa's crops are irrigated, the same percentages apply: 42 percent are located in water stress areas, and 74 percent will experience worsening water stress by 2025. Africa is dominated by rainfed agriculture, much of it in low water stress areas, a positive sign for irrigation. But by 2025 water stress will worsen for nearly half of Africa's agricultural areas. "We definitely need to irrigate a lot of Africa," Iceland said. "But this map serves as a warning sign. … Ask yourself: Is that water going to be available for irrigation use in the near future?"

When demand outstrips supply, the economic consequence is a rise in prices. Since 2002, food prices have increased steadily, punctuated by price spikes in 2008 and 2011. The human implications are that well-being and human health will deteriorate. "And when people go to sleep hungry and they see their kids go to sleep hungry, they get angry. … And when people get angry, they go to the street and they protest in days of rage," Iceland said, adding that recent protests in the Middle East may have been due partly to food.

Solutions

Increasing yields won't be enough to raise food production the necessary 70 percent by 2050, Iceland said. Fertilizers and pesticides may help but also contribute to nutrient pollution and other water quality problems. Expanding irrigation is also part of the solution, but will water be available? he asked.

"My preferred solution, my first best solution, would be not to waste the food in the first place. And there's a shocking amount of waste," Iceland said. According to the Food and Agriculture Organization of the United Nations, one-third of food produced globally for human consumption is lost or wasted. This occurs at every point in the food supply chain, from production and processing to consumption, and within every food group. If agriculture's share of total global water consumption is about 80 percent, then about a quarter of water consumed is wasted via food losses and waste. Without those losses, available food would increase about 50 percent. "Why don't we put a big dent in that 70 percent (food production increase required) by eliminating our food losses and our food waste?" he asked.

Alida Vanni, iStock

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Agricultural Producers Panel – A View from the Field

Guillermo Belottini
Commercial Manager, LIAG Argentina

April Hemmes
Producer, Hemmes Farm, Iowa

Brandon Hunnicutt
Producer, Hunnicutt Farms, Nebraska

Mridula Sharma
Producer, India

Mark Gustafson, Moderator
Founding Director, Engler Agribusiness Entrepreneurship Program,
University of Nebraska–Lincoln

The panelists' farms represent a spectrum of geographies, sizes and operations, ranging from 18 acres (7 hectares) to more than 100,000 acres (40,000 hectares), from rainfed to entirely irrigated. Panelists discussed changes on the farm, how technology influences farming practices and ongoing challenges.

Argentina

LIAG Argentina embraces sustainable agriculture, which extends beyond economic viability and production to encompass ecological and social impacts, said Guillermo Belottini, LIAG commercial manager since 1995. Founded by the Australian Kahlbetzer family in 1982, LIAG owns 80,000 hectares (197,684 acres) and rents 20,000 hectares (49,421 acres) throughout Argentina.

The company's commercial cotton brand, Tolloche Cotton®, is grown on Finca Tolloche in northern Argentina. With 60 percent of its 41,000 hectares (101,313 acres) irrigated, it is one of the country's largest irrigated farms. In addition to 12,000 hectares (29,652 acres) of cotton, the farm grows wheat, maize and soybeans.

Once solely gravity irrigated, Finca Tolloche takes water from the Palometa River, sending it 48 kilometers (30 miles) via canal to the fields. Laser leveling improves irrigation and allows

Guillermo Belottini

From left, Mark Gustafson, Guillermo Belottini, April Hemmes, Brandon Hunnicutt and Mridula Sharma

water to be collected at the lower end to irrigate additional fields. To increase water efficiency, the company began purchasing mechanized linear irrigation systems in 1995. Today, 21 linear systems irrigate 14,200 hectares (35,088 acres), and 11,000 hectares (27,181 acres) are still gravity irrigated. Seeking even greater productivity and efficiency, LIAG installed 18 capacitance probes to measure soil moisture levels for better irrigation management. To protect soils, the farm practices no-till agriculture, plants wheat during the driest season and uses a stripper head to leave stubble. Genetically modified cotton and soybean varieties have improved weed control.

In 1998, LIAG began introducing precision farming strategies that have greatly increased production, Belottini said. Noticing variability within fields, the company introduced yield monitoring, from which it developed yield maps that demonstrated the need for site-specific management. The company began variable rate applications of seeds and fertilizer. Today, satellite images help producers decide variable rate applications of growth regulator for cotton crops. Other technologies introduced include auto-guidance systems, boom section controls in sprayers and, most recently, variable rate application in aerial spraying.

The farm must adhere to a few rules, including a recent requirement that land at high risk of erosion be set aside and a regulation regarding limits on contaminated water returned to the river.

Belottini said LIAG will continue mechanizing the remaining gravity-fed systems and adopting new, more complex technologies. The region's water distribution system also needs improvement, which will require government participation.

The company also is concerned about its social responsibilities, he said, citing contributions to a nearby village, including donating a library and land for a vegetable garden. Some employees work as volunteer teachers and help repair

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donated school furniture, and some employees' children receive scholarships covering housing costs and other college expenses. "We believe that everybody at our company contributes to our economic success," he said. "At the same time, we contribute to the development of our people and the community around us, and this is our commitment."

Iowa

April Hemmes has operated her family farm south of Hampton, Iowa, since 1985. In the Hemmes family for more than 100 years, the 1,000-acre (404.6-hectare) farm produces corn, soybeans and hay and includes a 30-head cow-calf herd. Like most Iowa farmers, Hemmes doesn't irrigate. Yields vary depending on weather, but corn averages nearly 200 bushels an acre and soybeans 50 bushels an acre. "We are fortunate enough to have the soils, the water and the climate very conducive for growing crops in Iowa," she said.

> *"Farming is one of those few professions where you can't just wake up one morning … and say, 'I want to be a farmer.'"*

Hemmes, interested in farming since childhood, graduated from college just as the 1980s farm crisis struck and farming's future looked grim. Determined to be a farmer, she returned to farm with her father and grandfather. She and her husband, who works in town, raised two children on the farm.

Hemmes has seen many changes, though not as many as her grandfather, who began farming with three blind horses, as he tells it, and at

April Hemmes

age 100 was still farming using auto-steer guidance on his tractor. Equipment advances allow Hemmes to farm by herself, with help in the busy spring and fall seasons. She hires someone to apply liquid nitrogen with grass herbicide to avoid using anhydrous ammonia. In the mid-1980s, the family still used a moldboard plow, but today she no-tills.

"The seed genetics, I think, are one of the biggest changes," she said. "Glyphosate or Roundup (Ready®) made me a really good soybean farmer." Last year she noticed weed resistance, so this year she used a broadleaf herbicide on both corn and soybeans.

To remove excess water from her fields, Hemmes recently installed tile drainage systems, networks of underground pipes that move subsurface water, allowing her to work in the fields sooner and providing a level planting surface.

"Water quality … is really a priority on our farm," she said. To reduce phosphorous and nitrogen runoff affecting water quality, the farm has wetlands, buffer strips and riparian areas. Hemmes also recently added wetlands on farm land that wouldn't drain sufficiently. She is

compensated for the land by the Conservation Reserve Program, a U.S. Department of Agriculture Farm Service Agency program that pays farmers to set aside environmentally sensitive areas. Because of concerns about nitrogen and phosphorus runoff, Hemmes said she envisions farming using nutrients even more precisely, but she worries about extra mandates and restrictions.

Nebraska

Growing up helping his father on the farm, Brandon Hunnicutt decided to return after finishing college in the late 1990s. Today, he lives with his wife and six children on the farm that has been in the family for more than a century. He farms 2,600 acres (1,052 hectares) with his father and brother, raising corn, soybeans and popcorn. The farm is fully irrigated.

Traditionally, the farm was flood irrigated. In the mid-1970s, the family began installing center pivot irrigation systems. At the time, the Hunnicutts also produced wheat, sorghum and seed corn for seed companies. Corn yields were about 150 bushels an acre.

When Hunnicutt returned to the farm, father and sons began considering how to become more efficient. The family decided to till, but no longer disk, the soil. After the introduction of genetically modified crops, the Hunnicutts began strip tilling, a modified form of vertical tilling, to 8 inches to ensure a firm seed bed for the next season and to retain residue that conserves water and keeps soils cool.

Over time, they began integrating different techniques to increase yields and efficiency and to maintain the soil and groundwater for the next generation. “I don’t want to be the last generation farming,” Hunnicutt said. “I knew my dad didn’t. But I want my sons or daughters to be able to come back to the farm and hopefully their children as well.”

They began using variable rate planting, fertilizing and irrigating. Suspecting they used more water than necessary, the Hunnicutts began working with the Upper Big Blue Natural Resources District and the University of Nebraska–Lincoln to use watermark sensors and capacitance probes to measure soil moisture levels. They found that irrigating less often didn’t affect yield. To further help with irrigation decisions, they began monitoring daily rainfall through the state’s Department of Natural Resources Nebraska Rain Assessment and Information Network and used evapotranspiration gauges.

Brandon Hunnicutt

Farming has become more mental than physical, Hunnicutt said. Today, 5 carefully timed inches of water annually produce up to 250 bushels of corn per acre while saving water, electricity and wear and tear on irrigation equipment. “It’s been really fun to see what we can do and still maintain our yields,” he said. “I’m excited to see where this goes.”

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He hopes greater understanding of water, crop and soil interactions leads to even more productivity. "If the goal is to push the U.S. national corn average to 300 bushels an acre, it's going to take a whole lot more than just what we're doing right now to really get to that point," he said.

India

Land reforms following Indian independence in 1947 dramatically altered agriculture, said Mridula Sharma, who farms with her husband in Uttar Pradesh, northeast of Delhi. Previously, under the zamindari system, owners of large landholdings employed tenant farmers to cultivate land. After independence, the system was abolished and landholdings were limited to 18 acres (7.2 hectares), with surplus lands given to landless laborers. Today, 45 percent of landholdings are 1.25 acres (0.5 hectare), and 83 percent are less than 5 acres (2.02 hectares). Even the largest farms are tiny, Sharma said.

Mridula Sharma

Formerly zamindars, generations of Sharma's family owned large landholdings in two neighboring villages. Reforms required the family to divide the land among family members and distribute the rest among the farm's former tenants. Today, the family owns 25 acres (10 hectares), a small farm, but still one just 2 percent larger than the 18-acre ceiling.

The Sharmas grow wheat and rice as primary cash crops as well as mung beans and dhencha in rich alluvial soil. The farm receives nearly 100 centimeters (39 inches) of rain yearly, principally during the monsoon season from the end of June to mid-September.

When their children were young, the Sharmas left the farm with family and moved to the city. Farmers earn very little, she explained. More than half of their proceeds go toward expenditures, so the Sharmas net about $6,000 a year, too little to decently support a family. Lack of basic services, such as good health care and educational facilities, also contributed to their decision. After the children were grown, the Sharmas returned in 2005 to again oversee the farm.

They use their savings to improve the farm and village. Previously, the Sharmas irrigated with canal water and oxen-drawn well water. Diesel engines eventually replaced oxen, and today they use electric tube wells in addition to canals. Ox carts traditionally carried produce to market, but now they use open tractor-trailers or hire trucks. And tractors, harrow plows, combines and reapers slowly replaced manual plowing, sowing and harvesting. But most farmers can't afford modern implements for their tiny plots, and Sharma would like greater adoption of technology in India.

The Sharmas actively conserve water, making maximum use of canal water. Because the canal is available only on certain days for fixed hours, they also must irrigate with wells. To conserve water, they level the land at great expense. "Our

"When we are not earning a substantial amount of money, then how can one expect us to continue to do the drudgery just for nothing? But if everybody leaves, what will happen to our land?"

farm is in the northern plains. It is not a hilly area, but still we need to level it so that the land can be irrigated with a minimum volume of water," Sharma said. They also built cemented channels to transport water from tube wells and use no-till to conserve soil moisture.

Conclusion

Although the differences between their farms are vast, Hemmes and Sharma agreed that farming worldwide is losing young people. In India, village conditions are so poor that even basic needs go unmet, Sharma said. "When we are not earning a substantial amount of money, then how can one expect us to continue to do the drudgery just for nothing?" she asked. "But if everybody leaves, what will happen to our land? We are trying to inculcate some love in their heart for the land … love for the roots."

In the U.S., Hemmes said, even those who want to farm often can't. "Farming is one of those few professions where you can't just wake up one morning … and say, 'I want to be a farmer.' You have to have the infrastructure to be able to come home because it's just too expensive otherwise." Farmland sells for $10,000 an acre in Hemmes' area.

In contrast, many young Argentinians are coming to farm as professionals, even without relatives who farm or own land, Belottini said. Enticing people to the country can be difficult, so offering them a good quality of life is important. Above all, they must be educated because of farming's increasing sophistication. "We need highly qualified people. We strongly promote training and education on these new technologies. Because for us, it is no more the future, it is the present challenge."

From left, Guillermo Belottini, April Hemmes and Brandon Hunnicutt

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Industry Leaders Panel

Natalie DiNicola
Vice President of Sustainable Ag Partnerships, Monsanto

Claudia Garcia
Senior Director, Global Corporate Affairs, Elanco

Graeme Jarvis
Director, Latin America Technology Innovation Center, John Deere

John Soper
Vice President of Crop Genetics Research and Development, Pioneer

Jeff Raikes, Moderator
Bill & Melinda Gates Foundation

Jeff Raikes, speaking at his fourth global Water for Food Conference, led a panel discussion with representatives from some of the world's leading agribusinesses: Monsanto, Elanco, John Deere and Pioneer. The corporations, along with IBM, are partners in the Global Harvest Initiative (GHI), established to address food security by increasing agricultural productivity.

Jeff Raikes

"While water is a challenge for the entire world … it's going to be felt most acutely by the world's poorest farming families," Raikes said. About 75 percent of the roughly 1.3 billion people living in extreme poverty depend on subsistence agriculture. Helping farm families feed themselves both improves food security and provides additional income to educate children and improve health care options.

The water for food challenge provides opportunities to work together in new ways, Raikes said. Collaborations induce innovations and new approaches, and the Bill & Melinda Gates Foundation believes strongly in private-sector participation. "The history of capitalism really has produced an efficient allocation of resources in society to produce goods and services, and we think that's a very important part of the overall system," he said.

From left, Jeff Raikes, Natalie DiNicola, Graeme Jarvis, Claudia Garcia and John Soper

Market opportunities allow capitalists to take risks, and efforts to create profits can make a difference. Public sector governments, in contrast, provide services to improve quality of life but often won't risk public funds. Philanthropies like the Gates Foundation can act as catalysts: identifying areas of market failure, determining appropriate investments and seeking innovative interventions, which can then be scaled up or sustained by the private and public sectors. This catalytic philanthropic role requires working effectively with both the public and private sectors.

Systems-based Approach

Panelists agreed collaborations are critical and described how their companies are moving beyond traditional domains to encompass systems-based approaches. Graeme Jarvis of John Deere said that three levers are universally acknowledged as necessary: mechanization, genetics and irrigation. "If you put yourself in the shoes of a grower, a farmer, you don't look at (these levers) as point solutions. You're trying to put the whole system together," he said. How can companies, providers and universities worldwide leverage solutions from each lever to bring a system-centric solution to bear? "That's where a lot of the latent potential exists already today."

One of the company's strategies, John Deere FarmSight, includes three pillars: optimizing mechanization, logistics optimization and agronomic decision support. Technology gathers on-the-ground data then processes the information to determine the best strategy for the current season and for future seasons. Companies globally have more interest in farm-generated information, which will drive productivity worldwide, Jarvis said

Expanding irrigation also demonstrates the need for a systems approach. About 18 percent of the world's crops are irrigated but produce 40 percent of the food. Putting irrigation into practice and

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Graeme Jarvis

achieving its capabilities, however, requires understanding plant physiology, soil type, water quality and often water engineering, Jarvis said. Irrigation also requires overcoming farmers' aversion to risk and desire for a return on investment.

Catalytic philanthropy can help overcome these obstacles, Raikes said. Visiting an Ethiopian project with the nonprofit International Development Enterprises (iDE), he witnessed how philanthropy created a market opportunity to manufacture small pumps and then helped farmers determine how to invest in them. "Unless you have that sort of catalytic bootstrap, it's very difficult to do," he said.

Collaboration

A systems approach necessitates collaborations, panelists agreed. As members of GHI, the corporations are committed to working together to achieve food security through productivity and efficiency.

The recent GHI Global Agricultural Productivity report includes water supply and demand information as well as an index to measure incremental advancements in animal, farm and grain production in specific countries, said Claudia Garcia of Elanco, a global animal health corporation. An animal production section details how many animals are needed to maintain animal protein diets in developing countries. The report is scientific, neutral and trying to find solutions, she said.

Natalie DiNicola of Monsanto said the report also demonstrates the importance of private sector investment to increase developing countries' productivity, particularly in Sub-Saharan Africa. She described Monsanto's participation in the Water Efficient Maize for Africa (WEMA) project. The public-private partnership, led by Kenyan-based nonprofit African Agricultural Technology Foundation, focuses on bringing tools to smallholder farmers. Because drought hits somewhere in Africa each year and severe droughts occur regularly, farmers don't buy basic inputs for fear of losing that investment. WEMA formed partnerships to give farmers more yield stability so they can purchase basic inputs.

Monsanto has donated royalty-free transgenes and lines from its proprietary germplasm to add drought tolerance to African germplasm pools, DiNicola said. Once developed, WEMA varieties will be available to seed companies in Africa. Companies would like Sub-Saharan Africa to have a robust agricultural system and competitive marketplace so they can compete to earn farmers' business, she said.

Pioneer's John Soper agreed. "I think a lot of people assume that large companies don't work with small farmers, and it's simply not true." Small landholders are potential customers who can benefit from Pioneer's technologies, he said. The company has millions of customers in India and China and is expanding into Africa.

Small-scale farmers, particularly in Asia and Africa, present unique challenges, such as financing for

inputs and extension services to teach farmers to use new technologies, Soper said. Through acquiring a South African seed company, Pioneer committed to working with the government on extension services. It also collaborates with governments and nongovernmental organizations (NGOs) on U.S. water quality and African drought tolerance projects.

John Deere also recognizes the challenges specific to smallholders, Jarvis said. To better understand emerging needs and trends in tropical agriculture, the company recently opened new global centers with plans to expand. In addition, John Deere Water-India developed basic gravity-fed irrigation kits with a market supportable price point. The company is now leveraging the program to bring it to smallholders in Sub-Saharan Africa.

Natalie DiNicola

Garcia said Elanco also collaborates with NGOs, citing its work providing technical support and encouraging employee donations to Heifer International, which helps families with animal production.

Public Policy

DiNicola said the recent 2012 G8 Summit demonstrated that food security discussions are moving in the right direction. The public and private sectors focused on solutions, not problems. Governments identified policies needed to encourage private sector investment, and the private sector considered risks it must take to encourage market opportunities. "They weren't focusing so much on what the other camp needs to do. They were asking themselves: What do I need to do?" she said. "I think it's a really exciting kind of momentum."

In particular, 45 world companies, half of them African, committed to investing in Sub-Saharan Africa over the next decade to improve agricultural productivity. And some African governments have expressed willingness to reform policies to enable investments and add transparency in conducting business, DiNicola said. Panelists agreed that to invest in countries, technology companies need business-friendly environments that support them. That environment must include regulatory systems as well as basic laws or rules of accountability so that today's rules are the same tomorrow, DiNicola said. More governments recognize what a business-enabling environment entails, she said, but companies must explain their needs better.

Ethical Considerations

Raikes asked panelists to respond to criticism that companies are getting small-scale farmers in developing countries accustomed to using unaffordable technologies, thereby undermining sustainable agriculture.

DiNicola said she's been well received by farmers excited to have companies consider them potential customers. While traveling in Africa, she met a woman farming a garden of less than 5,000 square feet to support eight children, using poor quality seeds an organization had given her. "She felt like she just had no choice," DiNicola said.

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"And it really struck me how important it is for us to always ensure that farmers have choices. Even if they don't have a lot of money, they want to have choice, and they want to have ways of bettering their lives that are going to be sustainable into the future."

Instead of undercutting local markets through donated seeds, Monsanto provides vouchers that farmers can use to choose the seed they want. "What we found is that they overwhelmingly want to choose hybrid seed," DiNicola said. She sees a refreshing trend in understanding that companies' innovations are needed to provide farmers with choices. She's optimistic that the public and private sectors will work together to find sustainable solutions that keep farmers' needs and choices prominent.

Choice also is important when considering the rising demand for animal protein, Garcia said. A balanced diet provides more chances for a successful life and to fight disease, so animal protein must remain a choice for families. In the future, meat, milk and eggs will provide half the protein needed in developing countries and nearly one-third needed in developed countries. Elanco helps producers and governments meet animal production goals by calculating the animals needed, resources required and societal impacts. "Sometimes we make decisions based on a group of people, and we try to impose in general," she said. "We don't believe that's right."

Intellectual Property

Raikes said critics also say companies' intellectual property rights, particularly genetic technology patents, interfere with smallholders' access to inputs. What is the right policy to encourage innovation without preventing access? he asked.

Claudia Garcia

Soper said Pioneer advocates for regulatory and legal systems that support patents because they provide a return on investment which, in turn, spurs investments in new technologies and geographic regions. Where Pioneer does business has much to do with countries' basic policies, including intellectual property protection laws. Weak laws or enforcement, lengthy adjudication and government instability create challenges and are reasons Pioneer avoids some African countries, he said.

DiNicola said intellectual property is no longer viewed as a barrier to technological diffusion. Instead, many public institutions consider a lack of science-based regulatory frameworks and business-enabling environments as a greater barrier.

From the audience, Simi Kamal of the Hisaar Foundation disagreed. The issue is related more to patenting and pricing than investment or technology, she said. Small-scale farmers worldwide are used to multi-cropping based on traditional wisdom. While these traditions may not sustain 9 billion people, the opposite approach isn't necessarily patenting seeds. "We have to find some way in the middle," Kamal said. "In these small farms, we're not really looking for really great technology because a lot of people have their livelihoods associated with these farms. They need handheld implements.

Patenting has caused a lot of havoc in our part of the world. … We must accept that a lot of this is about power, not necessarily about simply technology," she said.

Soper said he disagreed. "I think what we really want to do is offer growers options, including the small landholders of the world. In order to do that, we need a reasonable set of intellectual property protection laws," he said. "Again, we're not trying to force anything on anybody."

When asked where lines should be drawn between private and public sectors, given the powerful influence companies can exert on public policy, Soper said that Pioneer engages in policy discussions on customers' behalf. In the U.S., politicians don't consider policy changes benefitting companies unless it's important to customers because U.S. citizens vote, not corporations, he said. "I think we can work together between the public and private sectors to develop joint policy positions and then utilize a joint approach to make policy changes occur on a more efficient basis."

Raikes added that poor people typically don't have a significant voice so philanthropy can play an equalizing role. "I think good philanthropy could be a nice complement to the private sector in this case."

Another policy discussion under way is whether water would be more efficiently managed if it were priced, Raikes said. An informal audience poll found it split evenly on whether governments should create a water market.

Conclusion

DiNicola emphasized overcoming obstacles that prevented collaboration in the past. "Even though there are really big challenges here, there's a lot we can do if we're working together. And I think healthy skepticism is great. Cynicism, we don't have a lot of room for that, I think, for the kinds of things that we need to do."

Jarvis added that solutions must have economic benefits to growers and to the system. "It's good to have altruistic endeavors and want to do good, but at the end of the day, it needs to be economically viable and sustainable for any of these smallholders, all the way up to large commercial, to work, and I think you'll find that a lot of the solutions that are going to come on the market speak to that end."

From the audience, Mma Tshepo Khumbane, who spearheads the South African nonprofit Water for Food Movement, asked panelists not to forget the importance of civil society organizations such as hers that work on food security in their communities and are ready to be engaged. "Food security is a right, and it shall not belong in the box of business," Khumbane said.

John Soper

Raikes agreed civil society organizations – giving people a voice – are an important part of cross-sector collaboration. To take on big challenges, important work can take place working collectively across sectors: private, public, civic society organizations and catalytic philanthropy. The glass is half full, he said, and there is the opportunity to work together.

Blue Water, Green Water and the Future of Agriculture

Women, Water and Food Panel Discussion

Lilyan Fulginiti, Discussant
Professor of Agricultural Economics, University of Nebraska–Lincoln

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

Pooja Bhattarai, Panelist
Program Coordinator, Women's Rehabilitation Centre, Nepal

April Hemmes, Panelist
Producer, Hemmes Farm, Iowa

Mma Tshepo Khumbane, Panelist
Founder, Water for Food Movement, South Africa

Christina Pacheco, Panelist
Vice President, ORPLANA, Brazil

Simi Kamal, Moderator
Chairperson and Chief Executive Officer, Hisaar Foundation, Pakistan

Women farmers produce much of the global food output, but their roles remain largely unrecognized and their voices unheard, said Simi Kamal of the Hisaar Foundation. She led a panel discussion of women in agriculture that included farmers, scholars and policy advocates from around the world. They discussed the challenges imposed on women and the consequences to agriculture, water and society. They also suggested ways to advance women's role in agriculture to improve food security and reduce global poverty.


Simi Kamal

Men's singular role in society is production, while women have four roles: productive, reproductive, maintaining societal linkages and caregiving, Kamal said. Largely uncompensated, most of this work is disregarded as labor, and few countries consider it in economic production measurements, such as gross domestic product.

From left, Lilyan Fulginiti, April Hemmes, Mma Tshepo Khumbane, Simi Kamal, Christina Pacheco, Pooja Bhattarai and Ruth Meinzen-Dick

Yet in some countries, small-scale women farmers produce up to 90 percent of the food consumed. When home farming is included, women provide more than half of the world's agricultural workforce. Globally, 800 million people participate in urban agriculture, growing food in backyards and small plots, which contributes to household food security but is not always reflected in statistics.

Unacknowledged Role

Women actively engaged in agriculture often aren't viewed as farmers. When April Hemmes returned to the family farm in 1985, choosing to farm was an unusual choice for a woman. When Hemmes attended Iowa State University in the early 1980s, just 5 percent of animal science majors were women; today they account for more than 60 percent.

Hemmes and her husband, who works in town, raised two children on the 112-year-old family farm south of Hampton, Iowa. While raising corn and soybeans and a 30-head cow-calf herd on about 1,000 acres, Hemmes also sits on numerous boards and helps develop programs for educating women in agriculture.

"I am so fortunate to live in and farm in a nation where it's legal for me to farm," she said. However, gaining acknowledgement as a farmer has been challenging. "People often said, 'It's so nice you're helping your dad.' I was never really farming. I was helping my dad."

Ruth Meinzen-Dick of the International Food Policy Research Institute said society considers women as farmers' wives, not farmers, and women's produce comes from kitchen gardens, while men engage in high-value horticulture. "There's something different in the way it's perceived that women's production often isn't recognized. … The first step in this women's empowerment in agriculture is to recognize women as farmers."

In agricultural policy circles, the idea that recognition would be good for women doesn't go far, Meinzen-Dick said. But acknowledging

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women's roles also would benefit families. Strong evidence exists that assets under women's control reduce poverty and improve children's health and educational outcomes more than overall household level income.

Recognizing women in agriculture also would lead to better water management, she added. In most developing countries, much interaction occurs between irrigation and domestic use, so including women in decision-making would help blur the boundaries between productive and reproductive use and discourage rigidly compartmentalizing water use management. "If you look at multiple uses rather than just irrigation outcomes, a lot of the irrigation systems perform better," she said.

Lilyan Fulginiti of the University of Nebraska–Lincoln agreed. Economists normally view water as a common-pool resource; while access to a resource such as water isn't prevented, consuming it prevents others from consuming it. This situation causes a rush to use the resource, which leads to overuse. Left alone, the market fails to allocate common-pool resources efficiently. "We could get to an economic and ecological disaster," she said.

Economists recommend interventions to achieve economic efficiency. For water resources, recommendations often involve management, such as state-imposed quotas and pricing or other rules, collective action or assigning private rights and water markets.

However, economic analyses fail to account for user heterogeneity, she said. Men and women producers use water differently and have different attitudes toward human capital spending and resource conservation. Institutions also govern resource ownership rights for men and women differently. "The recommendations that we would give, if we don't consider the origin of agents, are going to be wrong," Fulginiti said.

Everyone using a resource should be involved in its management, she said. Often user groups are

From left, Lilyan Fulginiti, April Hemmes, Mma Tshepo Khumbane and Simi Kamal

"The first step in this women's empowerment in agriculture is to recognize women as farmers."

composed of men or landowners, but women use water for gardens and other needs. If women are excluded, rules are ineffective, causing overuse.

Meinzen-Dick said recognition is coming. The U.S. Agency for International Development is creating an index of women's empowerment in agriculture to use in the Feed the Future Initiative. Empowerment of women includes five dimensions: participation in agricultural decision-making, control over assets, control over income, leadership and time.

Environmental Consequences

Recognizing women as producers also benefits society and the environment, Meinzen-Dick said. Women seem more concerned about water quality because of health concerns, though more evidence is needed to confirm that difference and to determine its effects on water management decisions. Fulginiti added that women tend to think longer term than men, which has conservation implications.

Christina Pacheco, a sustainable development proponent, is the fourth-generation manager of a 441-hectare (1,090-acre) farm and sugarcane plantation in southern Brazil. She also serves on local and regional sugarcane boards. Pacheco spoke of the need to conserve land and water for future generations. Her father had set aside 20 hectares as a reservoir for the city's drinking water. In 1991, as a member of a river basins consortium, Pacheco voluntarily replanted 40 hectares of riparian vegetation around the reservoir and rivers. The farm also contains untouched native forest.

In 1997, Brazil established the National Water Resources Policy that views water as a public asset and a limited natural resource with economic value. During shortages, priority is given to drinking water and livestock. Each river basin is the basic territorial unit for water resource management, which is decentralized, open to public participation and integrated throughout all levels of government and users. All water use, from domestic wells to irrigation, must be authorized for specific purposes and for a limited time.

Christina Pacheco

A recent Brazilian law requires a portion of each rural property to be dedicated to native forest and riparian vegetation. In the Amazon, 80 percent of farms must be native forest, in the savanna 35 percent, and in other areas, such as Pacheco's farm, 20 percent must be native forest.

"We are not destroying our forests," she said. "We are trying to keep them because we think they're very important. Our land is the most important resource we have as farmers. … We know that we must grow, but sustainably," she said. The sugarcane sector also agreed to environmental protocols. In addition, strict labor

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laws and fair practices are in place, though stable and predictable economic policies are still needed.

When asked how she feels about the government dictating land use requirements, Pacheco defended the restrictions as necessary for future food security. She said her farm makes enough money that she didn't consider lost income due to riparian set-asides. "I need the water and I need it to be clean. So it's a kind of sharing with Mother Nature," Pacheco said. "That land belongs to the future generations of my family who will take care of it and will make it to produce food. … You have to produce, you have to be sustainable, and you have to do it right. Otherwise, what's the future of humanity? What's going to happen to the world if we don't take care of it?"

> *"What's going to happen to the world if we don't take care of it?"*

Rights and Resources

Women face many challenges as they produce food and tend their children, Kamal said. Micro-financiers target women for loans with much higher interest rates than commercial loans; multiple roles prevent many from leaving home for work or education; their incomes and profits are often expropriated by either the system or men in their families; and home-based farming receives little irrigation and infrastructure development spending.

Particularly challenging are the unequal rights many women endure. In some countries, separate rights are considered unnecessary because it's believed male family members can safeguard women's rights. Women own little of the world's agricultural lands and few assets. This lack of property rights renders women farmers powerless. Women can't drive agricultural change without equal rights or rights to property, Kamal said.

Nepal demonstrates the effects unequal rights and women's lack of resources have on food security, particularly as women's roles in agriculture increase, said Pooja Bhattarai of the Women's Rehabilitation Centre.

Nepal's strict patriarchal system legitimizes male authority over women, and gender discrimination occurs at household, community and national levels. The resulting lack of opportunities limits women's decision-making ability. "In order to make sure that the women of the household level do not face discrimination, it is equally necessary that there is a mechanism in place at the national level that doesn't discriminate (against) women and (that) assigns her and identifies her as equal citizens," Bhattarai said.

The patriarchal system also makes women more vulnerable to poor nutrition and chronic food insecurity. In Nepal, land is associated with social status and wealth, but women are systematically denied the right to own or inherit land, property and other assets. Only 11 percent of Nepalese women own land, of which just 3.5 percent is arable.

Agriculture, the most important economic sector in Nepal, comprises nearly one-third of the country's gross domestic product and involves nearly three-quarters of Nepalese households and two-thirds of its labor force. Half of all household incomes derive from agriculture.

Subsistence farming predominates, and Nepal doesn't grow enough food to feed its population. About one-fourth of Nepal's 27 million people are chronically underfed. "If the country improves

subsistence farming, then it has a large potential to improve the food security of the country," Bhattarai said.

Today, more women are involved in agriculture due to a decades-long civil conflict and high outmigration of men to work elsewhere. About 85 percent of employed women work in agriculture compared to 67 percent of employed men, though women's contribution is greater when unpaid family agricultural labor is included. This agricultural feminization has reduced production and productivity, but the government has yet to adopt measures to address these challenges.

Nepalese women are demanding equal rights. The government has committed to most major international obligations safeguarding human rights and gender equality as well as the right to food, but much effort is still needed to put these policies into practice, Bhattarai said. Gender initiatives are donor driven and not sustainable, and socio-cultural norms still bar women from meaningful participation in decision-making. "The government now should adopt all necessary methods to guarantee the access of women to natural resources and productive resources and also should come up with gender friendly food policy and safe drinking water policy," she said.

"We have to bring up some of these issues as rights issues, not only as market-driven solutions."

Kamal said Nepal demonstrates that "when we talk about food security and new directions in agriculture, we really have to tackle that equality

From left, Christina Pacheco, Pooja Bhattarai and Ruth Meinzen-Dick

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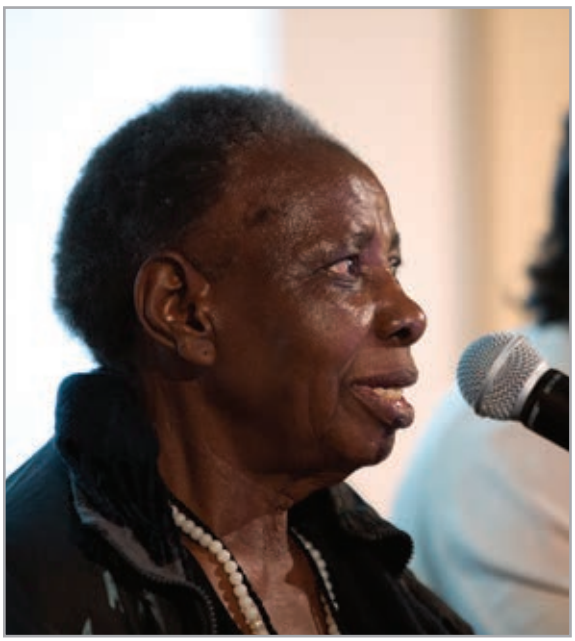
issue, and we have to bring up some of these issues as rights issues, not only as market-driven solutions."

Leadership and Education

Panelists agreed that a need exists for women in leadership positions. Hemmes said in her experience, women work more collaboratively than men and tend to prioritize families in decision-making. In the U.S., however, women have been uncomfortable managing farms or participating as leaders. She realized the importance of developing programs for women only. "In the United States, that's really what the focus has been because we have the right (to own land), fortunately. But it's just giving them the education and information to go on from there and help manage their farms."

Meinzen-Dick said she agreed, adding that if women in Iowa are uncomfortable in mixed groups, women are even more so in many other countries, illustrating the importance of building confidence through women-only groups.



Mma Tshepo Khumbane

Mma Tshepo Khumbane, a grassroots development activist and small-scale farmer, recognized the power of mobilizing poor women more than 40 years ago as a young social worker in South Africa when she vowed to fight hunger. Khumbane said she developed a sense of mobilization after seeing children from poor households admitted into hospitals with acute malnutrition. "That is where my strength came into being … and to realize the role food played in our lives. … I had to develop skills that I was not taught at school. I had to be innovative. I had to start now getting the courage to face the authorities, the tribal officers, the magistrate." Realizing she couldn't tackle chronic malnutrition alone, she began holding "mind mobilization" workshops to empower women to grow crops and vegetables within their homesteads. Her extensive networks evolved into a grassroots water for food movement, and she has since mobilized thousands of women.

More than a decade ago, at age 60, Khumbane purchased land to produce food. "Then I had to face bare land and say, 'I've been singing this song to the women, said you can work it, you can do it, you can produce your food.' Now I am physically demonstrating I can do it, here I am in the field with nothing … and now I've got to stand."

She built a house and developed a water management scheme that includes ditch irrigation, a borehole, rainwater catchments and gray-water recycling. By 2002, the 222-square-meter plot yielded more than a ton of food. Now, she has incorporated her farm into her mobilization programs. "I was not primarily looking at being a commercial farmer per se. I was sort of orientated toward: Can I contribute to elevating most of the problems that I have been handling for so many years in my professional work?" she said.

Including women in policymaking, collective action groups and universities is important to challenge how the world is viewed and studied, panelists said. "We have seen that institutional support mechanisms in a country coupled with women in leadership and decision-making positions help to support … not just women in agriculture, but agricultural advance as a whole. And women's empowerment in agriculture is a great agenda that we need to push at universities and at different levels," Kamal said.

Moving forward, interventions should target women and include men's support; women should be involved in designing and delivering innovative agricultural practices, products and services; and women's control over their economic gains must be protected. Policies should account for gender differences in responses to incentives and should invest in women as drivers of agricultural growth and food security.

Above all, women must be educated, panelists agreed. Fulginiti said, "It is only through the education of girls and women that they're going to change their ability to have assets, to have an income, and through that we're going to change the balance within the family and across the nation.

"Women would not only have a say in the family decisions or household decisions, but also will have more of a say in the destiny of their own nations."

Hemmes said she's encouraged that efforts to educate women are resulting in more U.S. women taking leadership positions and confidently managing farms. "Like I always tell people: the corn plant doesn't care who plants it, the soybeans don't care, the cows don't care who feeds them. The only limitations put on women are the limitations of society and other people."

"The only limitations put on women are the limitations of society and other people."

Blue Water, Green Water and the Future of Agriculture

Innovative Water Governance in Nebraska and Brazil

Ron Bishop
Manager, Central Platte Natural Resources District, Nebraska

Marcos Folegatti
Professor of Biosystems Engineering, University of São Paulo, Brazil

Mace Hack
State Director, The Nature Conservancy, Nebraska

Don Kraus
General Manager, Central Nebraska Public Power and Irrigation District

Oscar Cordeiro Netto
Professor, University of Brasília, Brazil

Christina Pacheco
Vice President, ORPLANA, Brazil

Edward Schrock
Schrock Land and Cattle Inc.; Former Nebraska State Senator

Ann Bleed, Moderator
Adjunct Professor, School of Natural Resources, University of Nebraska–Lincoln;
Former Director, Nebraska Department of Natural Resources (retired)

"In recent years, we have become more and more aware of the importance of having good governance structures to manage our natural resources for both current and future generations," Ann Bleed said. She led a panel discussion with representatives from Brazil and Nebraska, who described the unique governance frameworks in which they operate, the ways in which those structures are successful and the ongoing challenges of managing water while confronting competing interests.

Water Management in Brazil

In the last 20 years, Brazil has evolved tremendously in its institutional structure and tools for managing water resources, Oscar Cordeiro Netto said. Its legal framework is based on participatory management principles and an institutional framework established at national, state and basin levels. "It seems that our country, Brazil, is on the right track," he said.

From left, Ann Bleed, Marcos Folegatti, Oscar Cordeiro Netto and Christina Pacheco

Brazil has the world's sixth-largest economy and is the richest county in renewable water resources. Yet water scarcity and pollution are Brazil's major water problems. Nearly 70 percent of its water resources are located in areas with just 7 percent of the population. As both a downstream and upstream country, Brazil also shares water with 11 countries.

In 1988, a new constitution established two water domains: state jurisdiction for water confined to one state and national jurisdiction for rivers that cross state boundaries. Panelists agreed that diminishing water supplies and increasing pollution mobilized people to search for a better water management system, particularly in São Paulo state's Piracicaba, Capivari and Jundiaí river basins (PCJ), where a consortium was established to address regional water issues.

Turning Point in Water Resources Management

The decisive moment in Brazil's water resources management occurred in 1997 when a new law established the National Water Resources Policy, containing the principles and guidelines for integrated management that the PCJ region helped establish, Cordeiro Netto said. The river basin is the basic territorial management unit, and water domains continue under federal and state divisions.

The system incorporates regional, state and national plans and is governed by three managing principles: decentralization, participation and integration. Under the policy, water is a public good and a limited natural resource with economic value, which allows for use charges.

During water shortages, drinking water and livestock supplies receive priority.

To share responsibilities between the nation, states and river basins, the national policy established a framework involving decision-making, policy-making, and executive and regulatory functions administered by federal and state agencies. River basin committees are responsible for technical

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support and implementation. Water users and civil society participate in all aspects of the institutional framework, Cordeiro Netto said.

Oscar Cordeiro Netto and Marcos Folegatti

The law established five major tools for water management: water use permits and charges, classification of water bodies, a water resource information system and water resource master plans at national, state and river basin levels. Other important tools, not formally established by law, include capacity building and monitoring.

Brazil's National Water Agency is responsible for implementing the policy and supports river basin committees with planning, information, technical assistance and financial support. It also regulates water use, controls enforcement and makes rules. All water use requires authorization, at either the national or state level.

Managing federal rivers is challenging, Cordeiro Netto said. Federal rivers have many state-level tributaries, requiring water resource management at two levels of government. "Our permanent challenge was to implement the participation of states in terms of the national system," he said. Today, Brazil has 160 state-level river basin committees and 10 federal committees, and every state has a water council. Nearly half of Brazil is covered by an interstate master plan, and 13 states have state plans. Most plans are in areas of water use conflict.

A Successful Consortium

Brazil's watershed basin committees are based on the PCJ consortium's early success, Marcos Folegatti said. The PCJ region extends 300 kilometers (186 miles) and spans 62 counties in two states. More than 5 million people live in the 15,000-square-kilometer (5,792-square-mile) area, one of Brazil's most economically developed regions. High population growth rate combined with sugarcane production and high-tech industries continues to increase water demand. PCJ water also is transported to the city of São Paulo, causing regional conflict. PCJ supplies fall as low as 400 cubic meters during droughts, well below the United Nations standard of 1,500 cubic meters per inhabitant.

To address growing water problems, regional authorities formed the PCJ consortium. Today, it's structured around a unified assembly, consisting of federal, state and civil society members. Eleven chambers discuss individual topics, such as groundwater and industrial and rural uses. "We're talking about 700 people talking about the use of water in this area every month," Folegatti said.

Water basin plans guide management and must consider water quality problems, assess availability and demand, and describe goals and investments required, he said. About four times a year, the assembly meets to make decisions. Because issues have been discussed exhaustively in the chambers, assembly decisions are normally approved.

To fund studies and investments, the consortium agreed early on to a 1-cent tax per cubic meter of water use. Though difficult to implement and insufficient to fund everything, the revenue contributes to managing resources. The consortium invests heavily in soil conservation, particularly re-vegetating riparian buffer systems to improve water infiltration and water conservation during droughts.

Christina Pacheco, the fourth-generation manager of a 441-hectare (1,089-acre) farm and sugarcane plantation in southern Brazil and an executive on local and regional sugarcane boards, was an early consortium member and proponent of riparian re-vegetation.

In 1991, the PCJ consortium, the city of Capivari and a local sugarcane growers association agreed to cooperate on a reforestation program to control erosion and improve the environment.

Marcos Folegatti

Pacheco voluntarily replanted 40 hectares (99 acres) of riparian vegetation around her rivers and a 20-hectare (49-acre) reservoir her father had created to provide half of Capivari's drinking water. Twenty years later, Pacheco's trees are grown, and PCJ has planted more than 3.5 million trees on 2,000 hectares (4,942 acres) throughout the basin. Today, Brazilian law mandates replanting riparian trees around all rivers and reservoirs, and native trees must occupy 20 percent of an owner's land in São Paulo state.

"Mother Nature needed to be treated (well) because my soil is the most important asset I have. To have good production, I have to take care of my soil, and I have to take care of the environment," Pacheco said. "PCJ is a very important partner to protect water resources in our area." Its success lies in its organization and participatory governance, she said.

When asked about dealing with conflicts, Folegatti said the PCJ community gathers at meetings and seminars to discuss problems and share information. "There is no other way to convince people, if you don't have the right information," he said. Institutions, such as universities, are invited to conduct studies to provide information needed to solve problems. Cordeiro Netto added that negotiations are conducted within committees by establishing common ground and finding consensus solutions.

Challenges Ahead

Significant challenges remain in Brazil, panelists agreed, including increasing water services, especially sewage collection and treatment; reducing inequalities in water service access; abating water pollution; and guaranteeing sustainable water use, particularly given climate

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Christina Pacheco, Marcos Folegatti and Oscar Cordeiro Netto

change uncertainties and increasing demands. Power generation is another challenge. Hydroelectric power in the Amazon generates 72 percent of Brazil's energy, making it an important use of Brazil's rivers. Three large dams under construction in the Amazon will soon generate more hydroelectric power.

Nearly half of Brazil's water and two-thirds of consumption go toward irrigation. Brazil has the land and water to increase cultivation and irrigation in the coming decades, Folegatti said. The challenge is to plan effectively for growth and to encourage professionals and students to get involved.

Water Management in Nebraska

Unlike Brazil, the U.S. has no national water law. Except for a few federal law requirements, states manage their own water, Bleed said. In Nebraska, natural resources districts (NRDs), arranged around river basin boundaries, are responsible for flood prevention, sediment control, soil conservation, solid waste disposal, wildlife habitat, recreational facilities, forestry management and groundwater. NRDs are governed by locally elected officials with taxation authority and raise about half their funds through taxes and levies on irrigated areas. The state and other sources provide additional money, but funding remains a major problem, she said.

Nebraska's resources vary widely. Annual precipitation ranges from 17 inches in the west to 37 inches in the east. Rivers also vary. Groundwater-fed rivers continuously flow within the Sandhills, 21,000 square miles (54,390 square kilometers) of grass-covered dunes. Others may dry up in summer, including the Platte River, important for municipalities, recreational users, numerous endangered species and irrigators. Groundwater irrigation is also an important use of state water, and wells now number 130,000 statewide.

In Nebraska, surface and groundwater are managed separately. The state manages surface water permits, which date to the late 19th century, on a first-in-time, first-in-right basis, while NRDs manage groundwater as correlative rights in which water is shared during shortages, regardless of permit age.

Managing surface and groundwater separately has consequences, Don Kraus said. Studies have shown that as groundwater development increases, surface water supplies decrease. In the last 60 years, inflows to Lake McConaughy, a 1.7 million acre-foot (2-cubic-kilometer) reservoir important for irrigation, recreation and hydroelectric power, have decreased 26 percent.

Integrated Water Resources Management

In 2004, Nebraska enacted an integrated water resources management law, LB 962, that requires the state Department of Natural Resources and local NRDs to conjunctively manage efforts. Former state Sen. Edward Schrock, who helped create the law, said the most important aspect of LB 962 is that it requires the state to annually evaluate basins. NRDs declared fully appropriated must suspend all new well permits and develop an integrated management plan that includes data gathering, monitoring and identifying water for future development. Areas determined overappropriated also must take action to reduce water use.

Edward Schrock

Don Kraus

As chair of the Nebraska Legislature's Natural Resources Committee, Schrock, who operates a family farm, recognized that well drilling had harmful consequences. He and his colleagues formed a task force to solve some of Nebraska's water problems. "If we were going to sell it to the irrigators of the state, they had to be a very important part of the task force," he said. Farmers constituted more than half of the 49-member group, which also included NRDs, environmental groups and agricultural organizations.

"One of the things about the task force is we never took a vote," Schrock said. "One of the questions that was always asked: Can we live with this?" The task force functioned well, he added, but those opposed to drilling limits made the job harder.

Bleed said that endangered species on the Platte River play a large role in overappropriated designations.

Kraus said Colorado and Wyoming supply Platte River water, which in turn provides irrigation and Lake McConaughy inflow. The Central Nebraska Public Power and Irrigation District administers a significant hydro-irrigation project, which supplies hydroelectric power and irrigation

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for more than 200,000 acres (80,937 hectares) from Lake McConaughy and other sources, as well as recreation, flood control and groundwater recharge.

"Our issue was: How do we develop a cooperative approach to addressing those endangered species issues in the Big Bend reach of the Platte?" he said. To achieve greater water flows, a cooperative agreement between the three states, local entities and the federal government was negotiated, and the Platte River Recovery Implementation Program was formed.

Managing Over-appropriated Areas

Some areas within the Central Platte NRD are overappropriated and must contribute to Platte River recharge, Ron Bishop said. The NRD covers about 2 million acres (809,375 hectares) in central Nebraska, about half of which is irrigated, primarily with groundwater.

From left, Ron Bishop, Edward Schrock and Mace Hack

To reduce water use, the NRD began a water banking program, designed to reallocate water use away from areas with high impact on surface water flows, and has acquired surface water and groundwater rights from individuals. It also works with canal companies to purchase or co-own them or to reach management agreements to run excess flows to the river. Projects cost about $1,000 per acre-foot of water, compared to $5,000 an acre to buy out irrigated lands, Bishop said.

The NRD also manages flooding, in part by garnering federal, state and local cooperation to build floodways, and controls excess nitrate levels through fertilizer restrictions and an extensive farmer monitoring program.

These programs work because of trust, Bishop said. The 21 directors on the NRD's board are elected and impose regulations on themselves as well. Meetings are open to the public and comments encouraged. Although some resistance occurs, the public's response has been largely positive, he said.

Mace Hack said the Central Platte NRD's water banking program is an example of the innovation NRDs bring to solving problems at a local scale rather than searching for one-size-fits-all solutions. The NRDs are strong bodies for achieving local control and provide accountability and ownership. They also encourage more efficient groundwater withdrawal monitoring and understanding of how withdrawals affect resources than would happen at the state level, Hack said.

But local control also can be a liability, he said. Lack of coordination between NRDs hinders solutions to improve management across entire basins, and the state needs a mechanism that enforces NRD coordination. Schrock said that preserving the water policy task force would have helped coordination efforts, but Kraus added that without dedicated funding the task force couldn't continue.

Mace Hack

Hack said NRDs also lack a solid framework to facilitate more proactive approaches to water management. Though NRDs vary in attention to the environment, wildlife interests are generally introduced only because of federal law. "We should be able to solve our environmental issues from a more proactive stance and not be forced to the table by federal regulation when things have already reached crisis proportions," he said.

NRDs have broad responsibilities, but many focus primarily on water, he added. Crafting local solutions that constituents embrace is a powerful tool that could address other resource issues. "I look forward to that day when there's a more uniform, broad embrace of that natural resource mission across the state."

When asked if putting a dollar figure on ecosystem services would raise their value, Hack said some studies have investigated the impact of dewatered rivers on communities with economies reliant on the Niobrara and Platte rivers. The environment also provides pollination, water filtration and recharge, and Brazil's PCJ region demonstrates the low cost of allowing Mother Nature to filter water. Other services, such as aesthetic value, are harder to quantify. "I do think we underestimate some of the services that nature provides, and I think it's a great line of inquiry," Hack said.

Should the U.S. Have a National Water Policy?

Audience members questioned whether the U.S. should have a national water policy or should form regional boundaries to better manage resources. Bishop said states should retain control, and Schrock added that states can sue over water abuses, which amounts to a national water policy.

Hack said the Brazilian law is a compelling national water policy example and asked if a consistent national policy would be more efficient, given that federal laws already affect water management in a hodgepodge way that can be difficult to carry out. He also suggested that a stronger state policy would be a more holistic approach to managing water across NRDs and other entities. Some states, including Texas, tired of fighting legal battles stream by stream, are moving toward stronger state policies.

Additionally, some federal agencies are developing river basin-wide compacts for large river systems. Other efforts, such as America's Great Outdoors, seek to focus on large ecological systems and generate collaboration among federal, state and local jurisdictions. "I think as we talk about the ecological integrity of a river, it's very hard to disassociate that from the ecological integrity of the whole system," Hack said.

Blue Water, Green Water and the Future of Agriculture

Closing Panel

Ken Cassman
Robert B. Daugherty Professor of Agronomy, University of Nebraska–Lincoln; Chair, Independent Science and Partnership Council, Consultative Group on International Agricultural Research

Suat Irmak
Interim Director, Nebraska Water Center, Robert B. Daugherty Water for Food Institute, University of Nebraska; Professor of Biological Systems Engineering, University of Nebraska–Lincoln

Simi Kamal
Chairperson and Chief Executive Officer, Hisaar Foundation, Pakistan

Keith Olsen
Producer, Nebraska; Former President, Nebraska Farm Bureau (retired)

Prem S. Paul
Vice Chancellor for Research and Economic Development, University of Nebraska–Lincoln

Roberto Lenton, Moderator
Executive Director, Robert B. Daugherty Water for Food Institute, University of Nebraska

This panel discussion addressed critical issues raised during the conference, offered suggestions for future conferences and activities, and proposed priorities for the Robert B. Daugherty Water for Food Institute as it strengthens its mission to help the world efficiently use its limited freshwater resources.


Ken Cassman, Suat Irmak, Simi Kamal and Keith Olsen

Ken Cassman, University of Nebraska–Lincoln
The United Nations' Food and Agriculture Organization recently reported that food production must increase 70 percent to meet demand in 2050, Ken Cassman said. Some have suggested that reducing waste could reduce the figure to 50 percent, and changing diets could further reduce it to 30 percent. The potential to reduce waste

From left, Roberto Lenton, Ken Cassman, Suat Irmak, Simi Kamal, Keith Olsen and Prem S. Paul

and change diets is a new addition to the global food challenge discourse, and those figures suggest very different research and investment priorities, he said.

Waste can't be eliminated entirely, Cassman cautioned. In developing countries, it would require infrastructure, connection to markets and energy. By the time infrastructures are developed, the accompanying income rise will have further increased food demand. Similarly, as incomes increase, parents won't want to deprive their children as they were deprived.

"I think the danger is that we undershoot our projections, and thus our research strategy and policies," Cassman said, adding that growing demand would lead to dramatically higher food prices, increased hunger and greater environmental degradation. "I don't have the answers, but I think we need to be cautious about how we look at those two new issues on the radar screen."

He also discussed irrigated agriculture sustainability. Many people don't believe irrigation is sustainable, but future food demand can't be met without it – and the public's lack of understanding is dangerous, he said. The Robert B. Daugherty Water for Food Institute (DWFI) can play a role in benchmarking irrigated agriculture's environmental performance and ensuring improvement through better technology.

An audience member agreed that many people don't believe irrigated agriculture is sustainable, but added that they may be right, so dialogue and greater diversity of opinions at the conference are needed.

Blue Water, Green Water and the Future of Agriculture

Suat Irmak, University of Nebraska–Lincoln
Suat Irmak emphasized the importance of working together. "I think we all agree the challenges are great, and there's no way that one entity can achieve the success of addressing those water management issues or crop production for a growing population," he said, adding that strong partnerships among industry, universities, commodity boards, farmers and crop consultants are the keys to success.

Education and extension also play important roles. Scientific research is advancing, but to have an impact, research-based information must be disseminated to growers, crop consultants and others.

The University of Nebraska's (NU) Institute of Agriculture and Natural Resources has developed a water management network of crop consultants, farmers, natural resources districts, commodity boards and NU research and extension to improve productivity while establishing a balance between environmental and agricultural water uses. "I think it's a good example of working together with state and federal agencies, the university and farmers to achieve the productivity levels that we're trying to achieve," Irmak said.


Suat Irmak

Simi Kamal, Hisaar Foundation
Simi Kamal noted that water challenges are greatly magnified for women so it's important for DWFI to help inspire more girls to study science and to work toward filling more prominent leadership positions with women. Even successful women farmers face the glass ceiling, she said.


Simi Kamal

She urged the institute to connect with Nebraska's women farmers. Providing a platform for women farmers could later expand into programs that help women develop leadership in agriculture.

"We believe that institutional support mechanisms, like the ones we saw in Brazil, coupled with women in leadership and decision-making positions, can really help to support agriculture advances right across the world," Kamal said. "We need to invest much more for women as drivers of agriculture and food production."

Water use for domestic and irrigation needs has been separated for too long, she said. The two uses must be united to meet production challenges, and production must be balanced with environmental sustainability.

In addition, international seed companies need to think beyond the market as a redistributive force. "The market is not the only redistributive

mechanism, and we need to find others. Focusing on food security will really help us broaden that," Kamal said.

She also encouraged reducing waste and consumption. "We have to somehow work in such a way so that eating less becomes more fashionable," she said, adding that smoking, once considered glamorous, is now out of style.

Kamal suggested that DWFI add a practice component to its mission of research, education and policy advice and urged diversifying conference panels, such as adding to the industry panel people who can address pricing and patents' effects.

Keith Olsen, Producer

In the mid-1960s, when Keith Olsen returned to the family farm in southwestern Nebraska after college, his father raised wheat every other year with a year's fallow. Later, at the urging of crop specialists, farmers began planting corn in the wheat stubble.

Keith Olsen

When Olsen's son returned to the farm 10 years ago, he encouraged no-till sowing and a four-year cycle consisting of a year of wheat, two years of corn and a year of dry peas. Their yields have increased from a wheat-fallow-wheat rotation of 17.5 units annually to 56 units annually. "I think it can happen all across the world," Olsen said.

Biotechnology and equipment advances also have increased production. While some people can make organic farming productive, biotechnology must remain an option, he said.

Most important, producers must have choice. Olsen recently visited a farm couple in Vietnam, who proudly showed the American farmer their orange orchard planted in the mid-1980s after the government allowed producers to decide what to grow.

"That is my concern: Will I have the choice?" he asked. "I think it's extremely important … that producers have a choice to do what is best for their land and what's best for them."

Prem S. Paul, University of Nebraska–Lincoln

Community engagement has been the conference's strength and must be built upon, Prem S. Paul said. He would like more young people involved, as well as more collaboration with the community, partners and those who have invested resources in DWFI and its conferences.

"I think that clearly, if the institute is going to be unique and going to make an impact, research has to be a very strong part of that," Paul said. A multidisciplinary approach, engaging researchers from all NU campuses, is important in that effort.

But research must lead to solutions. Nebraska Innovation Campus is a place for public and private sectors to work together to learn about the challenges, develop tools and solutions and make them available worldwide. Water is one of the campus's three major focus areas, along with food and fuel.

"I have a challenge to all of us, especially to my colleagues at the University of Nebraska,"

Blue Water, Green Water and the Future of Agriculture

Prem S. Paul

Paul said. "I think we need to think big. I believe in a big vision and a short list. But if we can create a big vision, then things do happen." He cited the Global Yield Gap Atlas, spearheaded by Cassman, as an example.

Asked to describe the importance of yield gap analysis, Cassman said that food demand is now greater than supply, a reversal of the past 40 years. Food prices are rising globally, which decreases the disposable income that can drive other industries. Rising food prices also encourage farmers to produce more, often through expanding agricultural land. Protecting rainforests, wetlands and grasslands from expanding agriculture is vital to a sustainable future, he said.

"There's a critical need in the next five years to know exactly how much food every hectare of existing farmland can produce given its soil resource, given its climate and given its current cropping system," he said. The yield gap atlas provides that information for rainfed and irrigated agriculture. It is publicly available, transparent, scientifically robust and reproducible. For 40 years, knowing food production levels was unimportant, he said. Now, this information is urgently needed to inform policies and prioritize research globally.

When asked why reaching 9 billion people is an acceptable population level, Cassman responded that population control in the developing world had a bad reputation in the 1970s when some countries forced population control. Today, it's accepted that population control occurs when societies create enough wealth to educate girls because a strong correlation exists between population growth rate and educating women.

Kamal added that population control is a basic issue that must be solved in developing countries. Once women are empowered with equal rights and an education, they no longer want big families.

Irmak said that having a benchmark is useful to design, manage and plan resources, research and education. "Whether we accept (the number) or not, I think it's always a good idea to design or plan for the worst-case scenario."

Some solutions promoted at the conference seem unfeasible, said University of Nebraska–Lincoln Chancellor Harvey Perlman from the audience.

Global Yield Gap Atlas, http://www.yieldgap.org

From left, Ken Cassman, Suat Irmak, Simi Kamal, Keith Olsen and Prem S. Paul

For example, encouraging people to eat less, particularly less meat, has been unsuccessful and is an unrealistic assumption. Forcing that change through price would increase the gap between haves and have-nots and would decrease societal stability. In addition, it's politically unrealistic to believe a country would relinquish food security to another country, given the unpredictable nature of long-term relationships. Global solutions must be evaluated in the context of the world's reality, he said.

Audience member Victor Sadras of the South Australian Research and Development Institute commented that time scales are important considerations in developing strategies. Different technologies require different development lengths. A C4 rice variety, for example, may take 40 years to develop. If food is a concern for 2050, then allocating resources to C4 rice development is appropriate. However, if the crunch comes in 2030, C4 rice development becomes expensive. Targeting concerns to the appropriate time scales and allocating resources accordingly complement other criteria, he said.

Neil Palmer, CIAT/Flickr

Scientific Sessions

3

Scientific Sessions

Emerging Crop Technologies for Improving Performance in Tough Environments

Dirk L. Benson
Head, Project Trait Management, Syngenta

Mark Edge
Drought and Water Utilization Lead, Monsanto

Jeffrey Habben
Senior Research Manager, Pioneer

Leon Kochian
Center Director and Research Leader, USDA-Agricultural Research Service, New York;
Courtesy/Adjunct Professor, College of Agricultural and Life Sciences, Cornell University

Sally Mackenzie
Ralph and Alice Raikes Chair, Plant Sciences, University of Nebraska–Lincoln

Michael Fromm, Moderator
Director, Center for Biotechnology; Professor of Agronomy and Horticulture,
University of Nebraska–Lincoln

Scientific Abstracts

This chapter includes abridged versions of speakers' presentations during the conference's scientific sessions. Visit ***waterforfood.nebraska/edu*** *to read a full summary of each presentation.*

Dirk L. Benson

New Technology for Stressed Fields

Dirk L. Benson, Syngenta

Dirk Benson said Syngenta's Agrisure Artesian™ corn hybrid improves yields on dryland fields, on limited irrigation acres with low rainfall environments and on higher rainfall acres prone to moisture stress. He described Syngenta's Gene Blueprinting™ Technology, which identifies multiple

genes and distinctive modes of action responsible for moisture stress protection. These genes are then evaluated in managed and targeted stress environments. Plant breeding products don't face the regulatory requirements of transgenic products. Syngenta also conducts drought-related research and has a genetic modification program.

Breeding for Drought Tolerance

Mark Edge, Monsanto

Mark Edge described the biotechnology program that led to identifying cold shock protein B (cspB), a drought trait gene that causes plants to use less water and leads to higher yields under drought stress. After a gene is identified, tests under managed and field conditions, product development and regulatory work occur simultaneously. Monsanto's DroughtGard™ Hybrids have received U.S. approval for commercialization but await international approvals. Monsanto also is developing new drought-tolerant hybrids through a breeding program that combines native genes using transgenic technology. "I think one of the really encouraging things is the amount of germplasm diversity that there is already for drought tolerance," he said.

Mark Edge

Jeffrey Habben

Using Proven and New Technologies

Jeffrey Habben, Pioneer

Pioneer's drought tolerance program includes three parts: one builds on germplasm developed since the 1950s; another uses a native, non-transgenic approach that incorporates breeding and accelerated yield technology; and a third identifies transgenes to improve drought tolerance. Habben described studies demonstrating that the company's Optimum® AQUAmax hybrids outperform others in water-limiting environments with no yield reductions under favorable conditions. The company also is working on a transgene that would lead to achieving greater yields under drought stress without losing productivity under optimal conditions.

Scientific Sessions

Leon Kochian

Aluminum Tolerance Genes

Leon Kochian, USDA-Agricultural Research Service; Cornell University

Leon Kochian described the molecular toolbox he and colleagues are developing to understand and combat aluminum toxicity, which is especially problematic in areas where food security is most tenuous. They discovered and are investigating SbMATE, a major aluminum tolerance gene in sorghum, and are studying other aluminum-related genes. The team also is researching root system architecture through 3-D reconstructions and analyzing genome-wide associations to identify quantitative trait loci and associated alleles of important traits.

Breeding Epigenomes

Sally Mackenzie, University of Nebraska–Lincoln

Sally Mackenzie described the physiological effects – and potential agricultural benefits – of an epigenetic change she and her team generated in the expression of a ubiquitous plant gene. By eliminating the gene and crossing the phenotypically altered progeny with its wild type, Mackenzie is able to breed crop plants with higher yields and potentially greater tolerance to stress. "Breeding the epigenome … offers a whole new dynamic to the way we think about G x E (gene by environment)," Mackenzie said.

Sally Mackenzie

Groundwater Resource Assessment in Water-Stressed Regions: Past, Present and Future

Russell Crosbie
Research Scientist, Commonwealth Scientific and Industrial Research Organisation, Australia

Petra Döll
Professor of Hydrology, University of Frankfurt, Germany

Jean-Christophe Maréchal
Head, New Water Resources and Economy Unit, Bureau of Geological and Mining Research – French Geological Survey, Water Department

Imasiku Nyambe
Coordinator, Integrated Water Resources Management Centre;
Professor of Geology, University of Zambia

Marios Sophocleous
Senior Scientist, Kansas Geological Survey, University of Kansas

John Gates, Moderator
Assistant Professor of Earth and Atmospheric Sciences, University of Nebraska–Lincoln

Bridget Scanlon, Moderator
Senior Research Scientist, University of Texas at Austin

Scientific Abstracts

Visit waterforfood.nebraska.edu to read a full summary of each presentation.

Modeling Studies for Groundwater Systems

Russell Crosbie, Commonwealth Scientific and Industrial Research Organisation, Australia

Russell Crosbie described groundwater recharge modeling studies in Australia. He and colleagues used a one-dimensional soil vegetation atmosphere transfer model that relied on daily rainfall data from 16 global climate models to study diffuse recharge at the continental scale. Most areas with stressed groundwater systems and high groundwater extraction are projected to have groundwater decreases in the future, particularly in the South. "That's going to be a big policy challenge in the future," he said.

Scientific Sessions

Russell Crosbie

Abstractions Versus Recharge

Petra Döll, University of Frankfurt, Germany

Petra Döll described the results of modeling studies that assessed global crop virtual water content, as well as water stress and discharge changes due to human water use. Higher net groundwater abstractions occur in irrigated areas, although net additions to surface and groundwater also occur in some areas. Groundwater recharge is smaller than net abstraction in many areas, indicating groundwater depletion is occurring. However, much uncertainty regarding groundwater resources exists because there are so few precipitation global scale data sets, she said.

Petra Döll

Hard Rock Water Resources

Jean-Christophe Maréchal, Bureau of Geological and Mining Research, France

Jean-Christophe Maréchal said groundwater resources in hard rock are present in some water-stressed regions and can be used for irrigation. Because hard rock permeability and porosity are low, external factors are needed to improve hydrodynamic parameters. He described the rapid growth in India's groundwater use since the Green Revolution and the consequences of overexploitation. Scientists must better understand the relationship between the weathering profile and hydrodynamic properties to improve hard rock water resources, he said.

Jean-Christophe Maréchal

Assessing and Expanding Zambia's Resources

Imasiku Nyambe, University of Zambia

Imasiku Nyambe described efforts to assess and develop Zambia's water resources. The 2011 Water Resources Management Act provides a legal and institutional framework to plan and manage resources for economic development,

Imasiku Nyambe

and a new University of Zambia center studies water supply issues and mining's effect on water. Several factors continue to hinder groundwater development, including abundant surface water, lack of appreciation for irrigation and limited investments. "Zambia can succeed if we can capitalize on the implementation of our new act and not look behind," he said.

Water Laws and Sustainability

Marios Sophocleous, University of Kansas

Marios Sophocleous described key water-related laws and management practices in Kansas, which have worked to create a more sustainable water future. Kansas follows the prior appropriation doctrine of water allocation. To address groundwater overdevelopment, the state established local groundwater management districts, among other measures. But more is needed, including fewer restriction exemptions, greater stream protection and promotion of aquifer recharge and storage. "Although the future of the High Plains Aquifer in Kansas is uncertain, what is certain is that withdrawal in excess of recharge is not sustainable in the long term," he said.


Marios Sophocleous

UNL graduate student Jonathan Traylor

Poster Competition, Conference Participants and Photos

Appendix

Juried Poster Competition

The 2012 Water for Food Conference featured a juried poster competition for graduate students. Forty-one posters were entered in four key categories reflecting the major conference themes and a general category for other topics related to water for food. Additional posters were submitted by faculty, partners and other professionals and are listed below the students' entries according to category.

Photos of the winners present are included. Award winners are pictured with Roberto Lenton, founding executive director of the Robert B. Daugherty Water for Food Institute, and Jim Gaffney of Pioneer, which co-sponsored the competition.

Mats Lannerstad and Malin Falkenmark

Online Competition

University of Nebraska faculty and other Nebraska researchers 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): Tarlan Razzaghi, UNL
Using Airborne Hyperspectral Images to Estimate Green Leaf Area Index in Maize and Soybean

Second Place ($1,000): Natalia Uribe,
International Center for Tropical Agriculture, Palmira, Colombia
Implementation of the SWAT modeling in two Andean watersheds as a tool to determinate the hydrological ecosystem services and identify service providing units

Third Place ($750): Yuping Zhang, UNL
Accumulation of Salmonella *infantis in Soil and Vegetables after Irrigation using Wastewater Effluents*

Tarlan Razzaghi (right) with Roberto Lenton and Jim Gaffney

Viewer's Choice Competition

A viewer's choice competition was held at the conference. Those registered for the conference voted for the best poster during a poster session and reception sponsored by Pioneer, a DuPont Company. All winners received cash prizes and free registration for next year's conference.

First Place ($1,500): Baburao Kamble, UNL
Mapping Evapotranspiration from Regional to Continental Scale

Honorable Mention ($750): Kristen Skolaut, UNL
Determining the Effect of Flow Regime and Climate Variability on Native and Invasive Woody Species in a Riparian Ecosystem

Baburao Kamble (center) with Roberto Lenton and Jim Gaffney

Kristen Skolaut (center) with Roberto Lenton and Jim Gaffney

General Topics Related to Water for Food

Jurors

Lisa Durso, USDA-Agricultural Research Service, Lincoln, Neb.; **Ann Bleed, Peter Calow, Patricio Grassini, Robert Kuzelka, Jessica Torrion, Charles Wortmann, Arthur Zygielbaum,** UNL; and **Shawn Gibbs,** University of Nebraska Medical Center

Graduate Students

Omotayo Adeboye, UNESCO-IHE Institute for Water Education, Delft, the Netherlands
Sustainable Use of Land and Water and Rainfall Variability in Ogun-Osun River Basin, Nigeria

Maitham Al-Sammak, UNL
Role of BMAA (cyano-neurotoxin) in Nebraska Freshwater Ecosystems

Tyler Austin, UNL
Prioritizing Peri-Urban Development Principles: Eco-Agro Networks and Clustered Urban Developments

Sagor Biswas, UNL
Transport of Growth Hormones in Vadose Zone Soil after Land Application of Manure

Joana Chan, UNL
Growing Food for Growing Cities: Urban Agriculture for Social-Ecological Resilience

Juried Poster Competition

Sami Gabir, Indian Agricultural Research Institute, New Delhi, India
Effect of resource conservation technology and nitrogen levels on moisture conservation and production of sorghum (Sorghum bicolor *L. Moench*)

Federico Garcia-Suarez, UNL
What is the use value of the High Plains Aquifer services to agriculture?

Danielle Grogan, University of New Hampshire
Spatial modeling of contemporary crop yields in China under sustainable and unsustainable water use scenarios

Atefeh Hosseini and **Travis Yeik,** UNL
Assessing Vineyard Production Using Hyperspectral Imagery

Tshepelayi Kabata, UNL
Accounting for Greenhouse Emissions and Water Pollution in the U.S. Agriculture: Environmental Performance Analysis

Baburao Kamble, UNL
Mapping Evapotranspiration from Regional to Continental Scale

Aziza Kibonge, UNL
Water Scarcity, Climate Change and Agriculture in Sub-Saharan Africa

Goden Mabaya, UNESCO-IHE Institute for Water Education, Delft, the Netherlands
Refinement of principles and procedures for effective modernization of A1 model irrigation schemes in Zimbabwe: a case study of Igudu A1 Model Irrigation Scheme

Donald Pan, UNL
Induction of a viral community infecting nitrate reducing bacteria within a nitrate and uranium contaminated aquifer

Pamela Pena, UNL
Modulating Nitrogen Flux in Sorghum and Wheat

Tarlan Razzaghi, UNL
Using Airborne Hyperspectral Images to Estimate Green Leaf Area Index in Maize and Soybean

Wei Sujie, Institute of Water Resources & Hydropower Research, Beijing, China
Analysis of soil moisture evolution of Shanxi Province in Hai River Basin

Samuel Fissaha Tesfay, Haramaya University, Alemaya, Ethiopia
Effect of Irrigation on Soil Qualities under Different Management Practices Using Maize as Indicator Crop in Meremeti Watershed, Enderta Wereda, Tigray, Ethiopia (Case Study Hizaeti Wedi Cheber Earthen Dam)

Federico Trindade, UNL
Water, Temperature and Biomass Yield along the 41st Parallel

Yuping Zhang, UNL
Accumulation of Salmonella *infantis in Soil and Vegetables after Irrigation using Wastewater Effluents*

Other Entries

Megan Konar, Princeton University
Water for food: The global virtual water trade network

Mats Lannerstad, Stockholm Environment Institute, Sweden
Consumptive water use for global livestock production - green and blue trade-offs and synergies across regions and livestock systems

Jake LaRue, Valmont Industries Inc., Omaha, Neb.
Precision Irrigation of Rice: Four Years of Commercial Global Production

Nico Salmaso, Fondazione E. Mach-Istituto Agrario di San Michele all'Adige, Italy
Long-term decrease in water availability in the second largest river in Italy (Adige River): implications for crop irrigation and water supply

Alyssa Smola, Nebraska Association of Natural Resources Districts, Lincoln, Neb.
Nebraska's Natural Resources Districts: 40 years of Protecting Lives, Protecting Property and Protecting the Future

Emerging Crop Technologies

Juror

Charles Wortmann, UNL

Graduate Students

Fanuel Laekemariam, Haramaya University, Alemaya, Ethiopia
Seed Spreader for reducing teff seed rate

Other Entries

James Schepers, UNL
Sensors for Sustainable Management

Groundwater Resource Assessment

Juror

John Gates, UNL

Graduate Students

Can Liu, UNL
Relationship between Hydraulic Conductivity and Spectrum Reflectance Curve

Nathan Rossman, UNL
Can modeling Characterize Resilience of Groundwater Systems to Irrigation in the Western U.S.?

Kristen Skolaut, UNL
Determining the Effect of Flow Regime and Climate Variability on Native and Invasive Woody Species in a Riparian Ecosystem

Daniel Uden, Nebraska Cooperative Fish and Wildlife Research Unit, UNL
Future scenarios of biofuel production and land use change and impacts on regional agricultural groundwater use

Juried Poster Competition

Groundwater Resource Assessment (continued)

Other Entries

Dana Divine, UNL
Characterizing a Complex Groundwater Flow System using Airborne Geophysics

Tofik Ahmed Shifa, Haramaya University, Ethiopia
Synthesis and Characterization of Nano-Sized Iron/Aluminum Mixed Oxide Sorbent System for Removal of Phosphate from Eutrophic water

Innovative Water Governance

Jurors

Marc Andreini, Robert B. Daugherty Water for Food Institute, University of Nebraska; **Ann Bleed, Peter Calow, Arthur Zygielbaum,** UNL; and **Shawn Gibbs,** University of Nebraska Medical Center

Graduate Students

Tadesse Alemayehu Abitew, UNESCO-IHE Institute for Water Education, Delft, the Netherlands
Scenario Based Evaluation of Planned Water Resource Development around Lake Tana Catchment, Blue Nile Basin

Xuerui Gao, Institute of Water Resources and Hydropower Research, Beijing, China
Mapping soil water content at regional scale based on Distributed Hydrological Model: A case study in Handan, Hebei Province of China

Noemi Mancosu, University of Sassari, Italy
A More Sustainable Agricultural Water Use in Sardinia (Italy)

Pramod Pandey, Iowa State University
Predicting supplemental irrigation and potential rainwater harvesting for rainfed agriculture

Cristian Quispe, UNL
Chlorovirus populations among aquatic environments in Nebraska

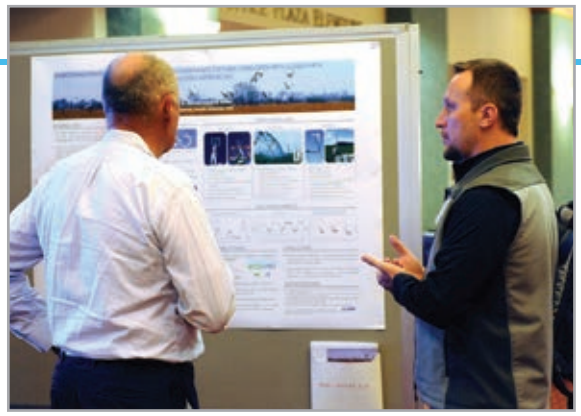
Sonisa Sharma, UNL
Discriminating Tillage Practices Using Landsat-5 Thematic Mapper

Michael Siek, UNESCO-IHE Institute for Water Education, Delft, the Netherlands
Optimal Crop-Water Planning Strategy Using Machine Learning Techniques

Agnelo Silva, University of Southern California
Communication and Sensing Technologies Applied to the Optimization of Water Usage: Irrigation in Large Farms and Subsistence Farming

Thubelihle Andrew Thebe, National University of Science and Technology, Bulawayo, Zimbabwe
Integrated groundwater and wastewater management for sustainable peri-urban food production systems in Bulawayo, Zimbabwe

Jonathan Traylor, UNL
Analytical model of irrigation and land use effects on stream flow in semi-arid conditions



George Burba, right, presenting his poster

Natalia Uribe, International Center for Tropical Agriculture, Palmira, Colombia
Implementation of the SWAT modeling in two Andean watersheds as a tool to determinate the hydrological ecosystem services and identify service providing units

Jaroslav Vido, Technical University in Zvolen, Slovakia
Conceptualization of a Drought Monitor for Conditions in the Slovak Republic

Yenesew Mengiste Yihun, UNESCO-IHE Institute for Water Education, Delft, the Netherlands
Optimizing Agricultural Water Productivity in Water Scarce Regions

Other Entries

George Burba, LI-COR, Lincoln, Neb.
Biosciences Evapotranspiration at Field Level from Eddy Covariance Stations using Open-path, Closed-path and Enclosed Approaches

Martin Schmid, Swiss Federal Institute of Aquatic Science and Technology, Kastanienbaum, Switzerland
Global agricultural green and blue water consumptive uses in the context of water scarcity and climate change

Sandip Shinde, Arts, Science and Commerce College, Indapur, India
Water and Soil Management by Continuous Contour Trenches in Pune District

Gary Zoubek, UNL
Nebraska Agricultural Water Management Network (NAWMN) Update

Women, Water and Food

Juror

Chantal Kalisa, UNL

Graduate Students

Anne Cafer, University of Missouri
Gendered Production: A Holistic View of Water, Resource Access, and Food Security in Female-Headed Households in Rural Ethiopia

Jill Moeller, Rhodes University, Grahamstown, South Africa
Introducing the Multiple-Use Water Services Framework and how it is welcoming people into water assessment processes

Conference Participants

Abbreviation Key:

iDE: International Development Enterprises
IWMI: International Water Management Institute
OWWDSE: Oromia Water Works Design and Supervision Enterprise
SIWI: Stockholm International Water Institute
UNESCO-IHE: United Nations Educational, Scientific and Cultural Organization-International Institute for Infrastructural, Hydraulic and Environmental Engineering
UNK: University of Nebraska at Kearney
UNL: University of Nebraska–Lincoln
UNMC: University of Nebraska Medical Center
UNO: University of Nebraska at Omaha
USDA: U.S. Department of Agriculture
USDA-ARS: U.S. Department of Agriculture-Agricultural Research Service
USDA-NASS: U.S. Department of Agriculture-National Agricultural Statistics Service
USDA-NRCS: U.S. Department of Agriculture-Natural Resources Conservation Service
USDA-RD: U.S. Department of Agriculture-Rural Development

Tadesse Alemayehu Abitew
UNESCO-IHE, the Netherlands

Lennie Adams
Valmont Industries Inc.

Zablon Adane
UNL

Keith Admire
USDA

Nwakaku Ajaere
UNL

Frank Albrecht
Nebraska Game and Parks Commission

Maitham Al-Sammak
UNL

Claire Althouse
Natural Resources Defense Council

Ryan Anderson
UNL

Marc Andreini
University of Nebraska

Maria Arellano
UNL

Adrian Ares
Virginia Tech

Andri Tri Atmojo
UNESCO-IHE, the Netherlands

Tyler Austin
UNL

Azzeddine Azzam
UNL

Jane Bachmann
Pioneer

P. Stephen Baenziger
UNL

Liz Banset
UNL

Ujang Wisnu Barata
UNESCO-IHE, the Netherlands

Brian L. Barels
Nebraska Public Power District

Jim Barr
USDA-RD

Laura Barringer
Global Harvest Initiative

Kelly Bartling
UNL

Cheryl Barts
NUtech Ventures

Albert Bassi
Syngenta

Mogens Bay
Valmont Industries Inc.

Guillermo Belottini
LIAG Argentina

Jim Bendfeldt
Central Platte Natural Resources District

Dirk L. Benson
Syngenta

Lorrie Benson
UNL

Bob Bergquist
Toro Micro-Irrigation

Richard Berkland
Valmont Industries Inc.

Tonya Bernadt
UNL

Pooja Bhattarai
Women's Rehabilitation Centre, Nepal

Charlie Bicak
UNK

William Binder
Rabobank

Ron Bishop
Central Platte Natural Resources District

Sagor Biswas
UNL

Jon Blasing
Syngenta

Ann Bleed
UNL

Audrey Boerner
UNL

Mary Bralts
Purdue University

Vincent Bralts
Purdue University

Joel Brehm
UNL

Michael Breitbach
UNL

Ryan Broker
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Conference Photos

Panoramic view of ballroom

Ken Cassman speaks with Don McCabe

Poster competition and reception

Martha Mamo

Richard Berkland, Mogens Bay and Martin Pasman

Kyle Hoagland and Olivia Sonderman

Mma Tshepo Khumbane and Pooja Bhattarai, both center, with participants

Conference Photos

Welcome banquet

Harvey Perlman

Ronnie D. Green

Victor Sadras

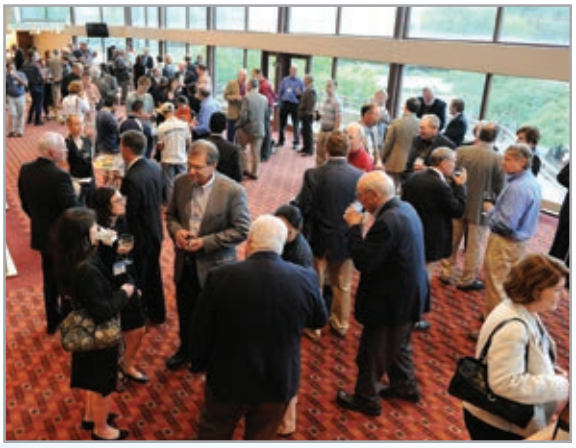
University of Nebraska Regent Randy Ferlic

From left, Ruth Meinzen-Dick, Roberto Lenton, James B. Milliken and Colin Chartres during a media briefing

Marcos Folegatti, Oscar Cordeiro Netto and Ron Yoder

Darryl White Trio

Mridula Sharma



Reception at the Lied Center for Performing Arts

Conference Photos

Wildlife photographer Michael Forsberg speaks at welcome banquet

Shant Karakashian and Simi Kamal ask questions during the Industry Leaders Panel

Roberto Lenton

Keith Olsen

Ronnie D. Green presents a plaque to Dean Edson honoring the Nebraska Natural Resources Districts for 40 years of innovative water governance

Graduate students attending sessions

Jeff Raikes

UNESCO-IHE students and advisers are recognized

Ag Tour Photos

Jerry Kenny speaks during a bus tour

Upper Big Blue Natural Resources District demonstration site

South Central Agricultural Laboratory near Clay Center, Neb.

UNESCO-IHE students

Marcos Folegatti

Post-conference tour participants

Suat Irmak

Suat Irmak leads a research demonstration

Walking through corn field

Learning about Nebraska's land and water