Advancing agricultural water security and resilience under nonstationarity and uncertainty: evolving roles of blue, green and grey water.

USDA/WRRC Track Insert
# 2014 Conference Program at a Glance - USDA Track Insert

Note: All USDA Track sessions are located in the Sophia Gordon Hall East-Multifunction Room, 15 Talbot Ave

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| Moderator: Richard Vogel, Tufts University | Moderator: Christopher Lant, Southern Illinois University - Carbondale | Moderator: Kenneth M. Strzepek, Massachusetts Institute of Technology |
| Robert Hisrich, U.S. Geological Survey | Arjen Hoekstra, University of Twente-Netherlands | Jay R. Lund, University of California-Davis |
| 10:00 Break (Cohen Auditorium Foyer) | 10:30 Break (Cohen Auditorium Foyer) | 10:30 Break (Cohen Auditorium Foyer) |
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| UCOWR Delegate Business Luncheon (Alumni Lounges) | USDA-NIFA Lunch | USDA Working Group |
| **Session 13: Agriculture and Sustainable Water Management** | **Session 32: Native American Perspectives on Water Management** | **Session 47: Colorado River Basin Water-Agriculture Nexus - Real-world management of water for people and nature** |
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| 4.15 Session 18: The Use of Shared Center Pivot Irrigation to improve Smallholders' Livelihoods in Africa | Moderator: Richard Berkland, The Valmont Company: "Piloting Center Pivot Irrigation Projects in Tanzania and Rwanda" | 4. Discussion |
| 3. Discussion | 4. Discussion | 4. Discussion |
| 5:30 Welcome Reception and Poster Session (Remis Sculpture Court, Hallway & Foyer of Aidekman Arts Center) | 5:30 Welcome Reception and Poster Session (Remis Sculpture Court, Hallway & Foyer of Aidekman Arts Center) | **Session 47: Colorado River Basin Water-Agriculture Nexus - Real-world management of water for people and nature** |
| 7:00 Dinner on your own | 7:00 UCOWR Awards Banquet (Winthrop Street Function Hall) | 12:00 Plenary VI - Does Integrated Water Resources Management Work? (Cohen Auditorium) |
| **Session 28: Case Studies from the Northeast & Mid-Atlantic** | | Moderator: Kenneth M. Strzepek, Massachusetts Institute of Technology |
| 1. Amy Shober, University of Delaware: "How repeated droughts and high commodity prices fueled the expansion of blue water use for agricultural irrigation in Delaware" | | Jay R. Lund, University of California-Davis |
| 2. Doug Beegle, Penn State: "Strategic and Tactical Challenges for Water Management in the Chesapeake Bay Watershed" | | Dan Sheer, Hydrologics, Inc. |

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### Presentations

#### USDA Track sessions are located in the Sophia Gordon Hall East-Multifunction Room, 15 Talbot Ave

**Wednesday June 18th, 8:00 AM**  
**Session 4: Water Conservation Innovations for Climate-Resilient Agriculture**

**Water Quality Strategies and Approaches of the USDA Natural Resources Conservation Service**  
Wayne Honeycutt, Deputy Chief for Science and Technology,  
*USDA Natural Resources Conservation Service*

World population is projected to increase from just over 7 Billion in 2014 to over 9 Billion by 2050. To sustain this rate of growth, we must provide as much food in the next 40 years as has been grown in the last 500 years. However, from 1982 to 2007, over 41 Million acres of rural land in the United States was lost to development. These realities place major stresses on our natural resources – stresses that can be expected to increase. With over 70% of the land in the lower 48 states being privately owned, the fate of our environment and natural resources is not going to be decided on public lands, but by millions of farmers and ranchers making decisions every day on how to use those natural resources. USDA’s Natural Resources Conservation Service works with landowners across the U.S. to implement scientifically sound conservation decisions on their land. Comprehensive approaches for acquiring and developing new technologies, examples of supporting their implementation in innovative approaches, and quantifying the impacts of these investments will be presented as components of the USDA-NRCS strategy to enhance water quality.

**Improving Climate Resilience Through Smart Agriculture**  
Barbara Minsker, *University of Illinois, Urbana-Champaign*

The “Big Data” revolution offers great promise for improving agricultural practices to increase climate resilience. This talk will present findings from a John Deere-sponsored project to explore how data-driven approaches can enable more rapid and informed decision making in the face of increasing weather extremes and variability. Using publicly available data, a field readiness virtual sensor and improved soil moisture estimation enable farmers to better estimate when their fields are sufficiently dry for planting or require irrigation. A nationwide analysis of regional shifts in hydroclimate indicates which areas may need to begin investing in irrigation equipment or shift to more drought-tolerant crops in the future. Finally, needs for improving data collection and modeling to further enhance agricultural decision making in an increasingly uncertain world are highlighted.

#### Wednesday June 18th, 10:45 AM

**Session 9: Israeli Water Management for Agriculture**

**Management of Water Systems Under Uncertainty**  
Uri Shamir, Technion-Israel Institute of Technology, Haifa, and the Interdisciplinary Center, Herzliya, Israel

For those of us who operate on the interface between the professional domains of water and the decision making arenas, one of the toughest challenges is to prepare, present and explain recommendations that elucidate and explain uncertainties, their consequences, and how they can be taken on board when making management decisions. The plural "arenas" conveys the idea that they include, in addition to the formal decision makers, also a wide range of professionals who are on the sidelines of the specific matter being decided or in an opposing camp, as well as affected stakeholders, the media and the public at large.

Using examples, primarily from the Israeli water sector, the presentation will attempt to convey through cases and experiences these dilemmas and how they were and are being dealt with in practice.

**The Red Sea - Dead Sea Conveyance Feasibility Study, 2008-2013**  
Doron Markel, *Water Authority of Israel*

The level of the Dead Sea, Israel, declines at a rate of more than 1 meter per year. The decline stems from the increasing use of all available fresh water resources that flow into the Dead Sea. This is accompanied by severe environmental and ecological impacts including the development of hundreds of sinkholes along the shore of the Dead Sea causing damage to the surrounding infrastructure.

Water availability per capita in most of the Middle East is among the lowest in the world and has been even further exacerbated by the onset of the effects of climate change and the reduced rainfall in the region. Jordan is most affected by the shortage of water supply and in the capital Amman water is supplied once a week only.

The declining level of the Dead Sea coupled with the acute water shortage conditions, led to the opportunity of finding a single, integrative and comprehensive, solution for both problems. The idea which was devised in many versions over the years calls for the desalination of sea
Agricultural Virtual Water Trade and Water Footprint of U.S. States
Stanley Mubako, University of Texas

Virtual water transfer in the form of trade in water-intensive crop, animal, and industrial products can constitute a substantial part of the water supply and demand balance of both importing and exporting regions. International studies have identified the United States as the leading gross and net virtual water exporter. This study quantifies water footprints and internal virtual water flows for the forty-eight contiguous states in 2008 by examining the water requirements of eighteen primary water-intensive crops and livestock. States exported 196 and imported 191 billion m³ of water. Iowa, at 14.7 billion m³, leads a collection of eleven states in the North-Central portion of the country with over 4 billion m³ of net exports. Rather than arid Southwestern states, which are collectively slight virtual water exporters, populous states bordering the Atlantic and Gulf coasts were the leading net virtual water importers, led by Florida at 10.8 billion m³. Per capita measures also reflect these general patterns. Virtual water flows are large compared to total water withdrawals, evapotranspiration from rain-fed crops, or total water footprint in nearly every state, with several Eastern states importing roughly half their water footprint and some Midwestern states exporting more virtual water than they withdraw or consume domestically.

Global Water Challenge Through the Conservation Lens
Kari Vigerstol, The Nature Conservancy

The world faces a growing water crisis as it aims to meet increasing demands for food, energy and water, and as climate change increases the uncertainty of supply. The reality of this global crisis plays out in individual water basins in unique ways, and no one solution can address the complexities of the physical, social and economic factors impacting local water resource challenges. The Nature Conservancy aims to help secure water for people and nature by applying strong science, engaging a full range of actors and employing policies and collective action efforts that optimize water management at the basin scale. As agriculture accounts by far for the largest portion of the global water footprint, and especially in many of the world's most water-depleted basins, this sector is a major focus for the Conservancy. The organization works directly with farmers, engages with large companies who depend heavily on agricultural products in their supply chain, and collaborates with government agencies to help reduce the blue and grey water footprints of agriculture while sustaining or increasing production. The Conservancy leverages successful approaches by sharing knowledge and experience throughout the global organization and with a

Wednesday June 18th, 1:30 PM
Session 13: Agriculture and Sustainable Water Management
wide variety of partners in an effort to expand its impact. This talk will explore nature's role as both a target of sustainable water management and an important tool to help us get there, from both a global perspective and through examples of on the ground collaborations.

Downspout Politics: Formalizing Rainwater Harvesting in the U.S. and Worldwide
Katie Meehan, University of Oregon

Who owns the rain? As ‘green infrastructure’ like rainwater harvesting (RWH) gains popularity worldwide, surprisingly little is understood about how small-scale practices and technologies are institutionalized, and why this process succeeds in some places and fails in others. By compiling a database of 96 policies across U.S. states and territories, we examine how rain comes to fall under state jurisdiction: through which policy mechanisms, at what spatial scale, and with what effect. Our analysis indicates three major trends: (1) the ‘codification’ of water through administrative rather than public law; (2) the institutionalization of RWH using market-based tools like incentives and rebates; and (3) the proliferation of policies at different spatial scales, resulting in greater institutional complexity, new bureaucratic actors, and potential points of friction. Collectively, these trends mark a shift in the U.S. tradition of water governance – from a state-level to ‘shotgun’ approach – and further suggest that socio-legal complexity may actually encourage rainwater harvesting. Drawing on a closer analysis of Colorado and Texas, we argue that states with diverse legal traditions of water enable more successful regulatory environments for downspout alternatives. I conclude with initial insights from new comparative research on RWH policies and implementation efforts in Australia, Brazil, and Mexico.

Wednesday June 18th, 4:15 PM

Session 18: Applications of Center Pivot Irrigation to Improve the Livelihood of Small Farmers in Africa

The Use of Shared Center Pivot Irrigation to Improve Smallholders Livelihoods in Africa
Mark Andreini, Water for Food Institute

In Africa, variable rains often result in disappointing dryland yields. Irrigation improves yields by supplying water reliably to crops and allows farmers to make investments in improved seeds and inputs that they would otherwise not risk making. The center pivot is an irrigation technology that has not yet been widely used. This talk will discuss some of the constraints to and potential advantages of the use of shared center pivots to improve smallholder livelihoods.

Piloting Center Pivot Irrigation Projects in Tanzania and Rwanda
Richard Berkland, The Valmont Company

Smallholder farmers in Sub-Saharan Africa (SSA) are locked into a cycle of poverty: they lack capital for farm inputs, access to markets to sell their produce and rely on tiny plots of land to feed their families and generate income. A huge constraint is continued reliance on rain, as only 4% of land in SSA is irrigated compared with 20% worldwide. With reliable and efficient irrigation, the linkage between rainfall and the needed water for agriculture production is broken, resulting in the opportunity for successful harvests though out the year.

Technologies exist to escape the cycle of poverty using modern soil management and mechanized equipment which will increase labor productivity while modern irrigation, hybrid seeds and fertilizer will increase yields and incomes for farmers. The dominant approach to irrigation is to focus on so called “appropriate technologies”, either through down-scaling technologies or by using large-scale flood irrigation projects which have a history of providing irrigation water inefficiently before breaking down for lack of maintenance.

By contrast, Center Pivot (CP) irrigation systems are the dominant form of irrigation for medium and large-scale commercial farmers in the USA and other highly efficient agricultural economies, and are now being applied in developing nations as the preferred technology due to their cost effectiveness and ease of use. CP systems pumping from both surface water and sustainable groundwater sources enable multiple growing seasons per year on the same land while using up to 50% less water and ensuring uniform distribution across the entire field.

Thursday June 19th, 8:00 AM

Session 23: Case Studies from the Southern USA

On-farm Water Storage Systems and Irrigation Scheduling in Mississippi
Mary Love Tagert, Mississippi State University

Since the 1970’s, groundwater levels in the Mississippi Alluvial Aquifer have decreased as the number of irrigated acres in the Mississippi Delta has increased. Today, there are roughly 18,000 permitted irrigation wells dependent on water from the Mississippi Alluvial Aquifer, with approximately 50,000 new irrigated acres added both in 2011 and 2012. As concern has grown over groundwater declines and increasing fuel costs to run irrigation pumps, farmers have been implementing more irrigation conservation measures, such as on-farm water storage (OFWS) systems and irrigation scheduling tools. OFWS systems began appearing in the Mississippi Delta in 2010 in conjunction with examples of on the ground collaborations.
with the implementation of the Mississippi River Basin Healthy Watersheds Initiative (MRBI). OFWS systems are typically surrounded by fields that are padded and piped, directing rainfall and runoff to a tailwater recovery ditch, from where it is then pumped into a pond for storage. Water is pumped from the pond and used for irrigation at a later date. These systems offer farmers the dual benefit of providing water for irrigation and also capturing nutrient rich tailwater for on-farm reuse. The Mississippi Irrigation Scheduling Tool (MIST) is one irrigation scheduling tool currently under development as a web-based tool to help farmers manage and schedule irrigation. The tool provides an estimate of crop water use based on a “checkbook” approach that determines the water balance of the soil, plus water from rainfall or irrigation, minus water used by the crop or evaporated from the soil. Daily evaporation is calculated using the modified Penman-Monteith equation. The system automatically notifies the farmer if irrigation is required when the available soil moisture falls below a set threshold. MIST, which is being tested in selected areas in the MS Delta region, has a web interface that allows producers to access the information from anywhere through tablet computers or smart phones. This presentation will give an update on both projects, which should help decrease the groundwater withdrawal from the Mississippi Alluvial Aquifer.

**Precision Irrigation: An Opportunity for Dramatically Increasing Agricultural Water Use Efficiency**

George Vellidis, University of Georgia

Over the past two decades, irrigation has become essential to crop production in the southeastern Coastal Plain. As a result, the competition for available fresh water supplies is increasing. Ugly political and legal battles between competing users to secure access to water are taking place in a region where annual precipitation exceeds 1300 mm. If irrigated agriculture is to survive in this competitive environment, we must use irrigation water efficiently. Precision irrigation offers the potential for improving irrigation efficiency. One approach to precision irrigation is to integrate variable rate irrigation (VRI) with advanced irrigation scheduling driven by soil moisture sensor data. To quantify the potential of such an integrated system, we began a research and demonstration project whose goal is to develop a soil moisture sensor-based variable rate irrigation (VRI) control system. The control system consists of a wireless soil moisture sensing array with a high density of sensor nodes, a VRI enabled center pivot irrigation system, and a web-based user interface. The operational paradigm is that the field is divided into irrigation management zones. The soil moisture sensing array is installed to monitor soil condition within the zones and provide hourly soil moisture measurements to the web-based user interface.

At the interface, the soil moisture data are used by an irrigation scheduling model running in the background to develop irrigation scheduling recommendations by zone. The recommendations are then approved by the user (farmer) and downloaded to the VRI controller on the center pivot as a precision irrigation prescription. When the center pivot irrigation system is engaged by the farmer, the pivot applies the recommended rates. This presentation will describe our system in detail providing data from the components which have been completed and are operational.

**Reclaimed Water Use in Florida and its Role in Agriculture**

Larry Parsons, University of Florida

Reclaimed water has been safely and successfully used for more than 40 years in Florida and California. Reclaimed water in these states is regulated with restrictions more stringent than World Health Organization guidelines. In the U.S., Florida is currently the largest producer and California is the second largest producer of reclaimed water. Even though Florida’s average rainfall is more than 52 inches per year, Florida produces over 60 times more reclaimed water than Arizona. Reclaimed water is disinfected and more highly tested than other sources of irrigation water, and the safety of this water has been demonstrated in these and other states. Use of reclaimed water has steadily increased in Florida since 1992, and agriculture used to be one of the larger users of this water, primarily for microirrigation of citrus and vegetable crops. Public acceptance of reclaimed water has also increased, and crops grown with reclaimed water in Florida and California have been marketed without negative public reaction. Because of population growth and variable rainfall, other entities besides agricultural now are competing for use of this water. Recent issues of food safety have caused some to question reclaimed water, but there is no evidence of food safety problems with its use. While reclaimed water in Florida was initially promoted as a way to improve surface water quality, it has now become an important alternate source of water to help meet water shortages and urban demand.

**Beneficial Reuse in El Paso, Texas**

Scott Reinert, Hydrogeologist, El Paso Public Water Utilities

El Paso Water Utilities has four wastewater treatment plants located throughout the city (Northwest, Haskell, Bustamante, Fred Hervey). The city has been using treated reclaimed water for turf irrigation since 1963. A portion of the wastewater effluent from Northwest, Haskell, and Bustamante is being redirected into a water distribution system (purple pipe) for users of the reclaimed water. Reclaimed water serves the demand of...
golf courses, parks, schools. Steam electric power plants, and industries.

Since 1985, the Fred Hervey Wastewater Treatment plant has been producing effluent that meets drinking water standards. Treated effluent from this plant is used for golf courses, parks, and as cooling water for electric power plants.

El Paso Water Utilities is in the preliminary stages of an advanced purification project that would purify effluent to drinking water standards that would be blended with other supplies. Use of reclaimed water is beneficial component to the long term sustainability of the groundwater resource.

Thursday June 19h, 10:45 AM
Session 28: Case Studies from the Northeast & Mid-Atlantic

How Repeated Droughts and High Commodity Prices Fueled the Expansion of Blue Water Use for Agricultural Irrigation in Delaware
Amy Shober, University of Delaware

Drought is a persistent, long-standing problem for farmers on the Del-marva Peninsula and in many other Atlantic Coastal Plain states. Regional weather, crop, and soil conditions often result in periods of prolonged drought, leading to significant reductions in crop yield, economic losses to farmers, and reductions in nutrient use efficiency. Climate change scenarios for Delaware suggest increased variability of precipitation and extreme events and warmer temperatures will further affect crop production in Delaware. Delaware farmers responded to these challenges by installing irrigation systems, particularly for high-value vegetable crops and corn (driven by recent high corn prices). Irrigation allows farmers to stabilize crop yields, prevent serious economic losses due to crop failure, and manage fertilizer N more efficiently using fertigation. Today, approximately 20-25% of Delaware crop land is irrigated using mainly “blue water” that is delivered via overhead sprinkler, center-pivot systems for corn or drip irrigation for vegetables. Interest in expanding irrigated crop production is growing in Delaware and is supported by state and federal agencies interested in enhancing the profitability of Delaware agriculture and buffering against the effects of climate change. We describe the current use and potential expansion of irrigation for crop production in the Delaware including: 1) factors driving expansion of irrigation, 2) sources of blue and grey water for irrigation, 3) adoption of irrigation technologies, 4) estimates of future irrigation expansion, and 5) potential for competition among water users. We also assess the potential for irrigation to improve nutrient management and reduce nutrient losses, particularly for N.

Strategic and Tactical Challenges for Water Management in the Chesapeake Bay Watershed
Douglas Beegle, Penn State University

While water quantity is a serious issue, in regions like the Chesapeake Bay watershed, water quantity discussions are often overshadowed by water quality concerns. Water quantity and quality issues in agriculture in the Bay watershed are driven by both strategic and tactical considerations. For example, the cause of the nutrient pollution from agriculture in the Bay has usually been assumed to be due to mismanagement of nutrients on farms, a tactical problem. Consequently, the approaches to solving the problem have focused almost exclusively on changing management on farms. Major progress has been made in improving on-farm nutrient management as a result and improvements in water quality have been observed, but the health of the Bay remains a concern. An analysis of the structure of animal agriculture in the Bay watershed reveals that the problem is much deeper than simply mismanagement of nutrients on farms. A major underlying strategic cause is a regional nutrient imbalance resulting from an economically driven system of animal production based on importing large amount of the feed necessary for the animals from outside the watershed. Therefore, a long-term, sustainable solution to the problem will require much more than just changing on-farm management. To really solve this problem will require not only improved nutrient management on farms, but also a restructuring of the animal production systems to internalize the environmental costs of this structural imbalance of nutrients in the watershed. The challenge that must be met is how to accomplish this in a way that is environmentally and economically sustainable. Likewise, as water quantity issues become more prominent, we must not only consider the on farm management of water, but also the strategic dimension of water use in the watershed as a whole.

On-farm Water Management in Massachusetts and New England: An overview of practices, challenges and needs.
Rich Bonanno, UMass Extension

Water will continue to be an invaluable asset to farmers in Massachusetts; however, the quality of that water is under scrutiny. Food safety issues have come to the forefront of every type of plant and animal agriculture and the government as well as buyers are demanding standards. While all the standards are not yet in place, the hand writing is on the walls.

Water can contain many pathogens but food safety standards suggest that a quantitative test for generic E.
coli is sufficient to assess overall water quality. If there is suspicion or further issues, testing can be done for specific E. coli or other pathogens.

Water standards can be separated into pre-harvest and postharvest categories. Pre harvest water must meet recreational water standards. Currently the acceptable standard is an average of 126 cfu’s generic E. coli/100 ml water. Postharvest water must be potable. Standards can vary among states; however, FDA requires a level of 0 cfu’s generic E. coli/100 ml water.

Animal agriculture can affect water quality and farmers must be aware of the impact of animals on agricultural water. This includes runoff from land where animals are kept as well as runoff from areas where animal by-products, such as manure, are stored.

The impact of flooding on agricultural land is also of significance. Water not under the control of the farmer must be considered to contain E. coli or other pathogens and the harvest and sale of food after flooding can result in fines or imprisonment. Upstream issues are significant and a system that communicates potential runoff contamination to downstream users is a must.

This talk will provide an overview of the on-going efforts by UMass Extension and producers to adjust to these new standards. In addition it will identify the opportunities, challenges and needs for further research and education in Massachusetts and New England to obtain and maintain clean water which must be available to meet the needs of the agricultural community.

**Phosphorus Export from Cranberry Farms During the Harvest Flood: Patterns, Controls, and Solutions**

Casey Kennedy, Agricultural Research Service, USDA

Southeastern Massachusetts has historically been one of the most important regions for cranberry production in the U.S. Economically viable cranberry production requires additions of phosphorus (P) making cranberry farms likely sources of P to surface water. For the cranberry harvest, periodic flooding is a common cultural practice used by 90% of the growers in Massachusetts. Although harvest flooding represents an efficient and cost effective management tool, the discharge of these floodwaters has been implicated as the major export of P from cranberry farms to nutrient sensitive waterways. In 2012, research was conducted to quantify the magnitudes and patterns of P export from cranberry farms during the harvest flood. Detailed sampling of cranberry floodwaters showed a wide range in P export, from 0.01 to 12 kg P acre⁻¹. Among the four farms studied, three sites had P export values that were close to zero, indicating that these farms were not significant sources of P to surface water during the harvest flood. The distinguishing characteristics of the farm having high P export included (1) elevated soil P and organic matter concentrations and (2) conventional ditch drainage, both of which are common features of older non-renovated cranberry bogs. Across all study sites, P was transported predominately as particulate P, representing about 75% of the total P load in flood discharge. New research on the application of a sand filter bed for reducing particulate P in floodwaters is currently ongoing at a cranberry farm near Monponsett Pond, which has been listed in category 5 in the Massachusetts list of impaired lakes and ponds. Installation and design of this P remediation technique to cranberry floodwaters will be discussed, as will the application of P-binding materials, such as gypsum.

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**Thursday June 19th, 1:30 PM**

**Session 32: Native American Perspectives on Water Management**

**Hopi Agriculture in the Changing Physical and Social Environment**

Matt Livingston, Hopi Tribe Office

The last 130 years have seen changes in the physical and social environments of the Hopi people. Agriculture has remained important for cultural and dietary purposes. The Federal government, through various agencies, has played a part in changes such as a lessening of land use for traditional farming that have happened. Often programs, such as the Dawes Act or General Allotment Act of 1887, did not fit into Hopi cultural practices or the environment. This act attempted to change what was Tribal Trust Land into allotments which would have challenged the Hopi tradition of passing property from mother to daughter undermine the societal security of women. In modern times, USDA program like the Environmental Quality Assistance Program have been a very poor match for farmes who live on Federal Trust Land. Understanding the culture and place and Tribal laws are necessary for outside institutions before proposing programs. Listening to the community, respecting their knowledge, letting the community determine what matters most to them, can help outside institutions when participating in the community. This includes understanding that farming is more than an economic practice in the Hopi community; it is very much a cultural practice. Farming at Hopi is not a money making endeavor.

**Collaborative and Resilience Water Management Planning Under Climatic and Non-Climatic Stressors for Southwestern Tribes**

Karlietta Chief, University of Arizona

Native Americans are deeply connected to the natural environment and tribal cultures, traditions, and identities are based on the land and sacred places that shape their world.
Government policies, land ownership, and permanent residency force tribal communities to not only live sustainably but to live sustainably under the stressors of short- and long-term climate change, local population growth, and water demands from upstream or downstream non-Native urban communities. These climatic and non-climatic stressors threaten tribal value system and livelihood and have severe cascading impacts through the biophysical environment and human- societal systems. In Arizona alone, there are 21 federally recognized tribes comprising 4% of the total population and nearly one-third of total land. These tribes generally have fewer water supplies of low quality and are situated in regions with lower rainfall that are subject to extremes in temperature and weather conditions. In spite of challenges such as these, tribes have continued to practice a lifestyle with strong links to environmental conditions, because of cultural ties to the land that take the form of gathering herbal medicines, hunting, and traditional agricultural practices. With the increasingly limited water supplies due to droughts, climate change, and urban growth, there will be an increasing competition for water by tribes, cities, agriculture, and endangered species. This demand will be amplified by stresses caused by climate variability. We established a stakeholder-relevant collaboration between the University of Arizona and southwestern tribes particularly the Navajo Nation in AZ and the Pyramid Lake Paiute Tribe in NV focusing on collaborative management of coupled natural-human systems. We integrated (1) the quantifiable impacts of climate variability and change on water and the environment within (2) a stakeholder collaborative process focused on finding viable alternatives and trade-off solutions to existing problems. This set the foundation for a science-fed collaborative planning and management arena for the tribes, drawing both from native knowledge and understanding of the land and local practices, as well as science and technology tools from the university and beyond. We aim for this participatory mechanism to be also a catalyst for capacity building, and mutual understanding of coupled natural and human systems, and will ultimately inform and benefit decision and policy-making related to water and the environment.

Irrigation on the Navajo Nation, Experiences and Recommendations
Ed Martin, University of Arizona/Maricopa County Coop Ext

In 1997, work began on a drip irrigation demonstration project in Tuba City, on the Navajo Nation. The objective of the project was to demonstrate the water savings potential of drip irrigation for the production of corn and squash. Funded through the USDA, the project was in place for two years and was able to demonstrate the water savings through drip irrigation. However, the notion of using drip irrigation did immediately catch on and the equipment fell into disrepair the following season with no one taking the lead at the local level. In 2005, a grant funded by the US Bureau of Reclamation looked at a comparison of drip irrigation and surface irrigation for the production of corn, using gravity fed drip. Typical figures show that 70 percent of the Navajo Nation had no water and families have to travel up to 70 miles in order to replenish their supply (Clauschee, 2006). The demonstration/research project took place at the Hubbell Trading Post, the longest, continuously operating trading post on the Navajo Nation. Here, visitors and local residents alike, were able to view the plots and see the benefits of drip irrigation for the production of corn. The two year study concluded that drip irrigation could be used for small garden like areas for the production of corn. Unlike the trials at Tuba City, this time, the drip irrigation began to take root. First, there was the local Land Grant College, Diné College, which took the concept of a small gravity drip system into a much larger system. Between these two efforts, there were several other inquiries from residents of the Nation. In the Canyon De Chelly, where residents of the Nation owned land, they wanted to install drip irrigation on their fields so that the little water available to them would be used at the highest efficiency. Most of the land owners lived outside the canyon and would drive or walk in weekly, sometimes more often, to tend their fields at the bottom of the canyon. In 2007, a large drip system was installed in Canyon del Muerto, a side canyon within Canyon De Chelly national monument. Here the grower used a solar panel connected to a well pump to deliver water to a well directly into the drip system. In another case, the growers wanted to use a generator to pump water from a well directly into the drip system. Another location, North Luepp Family Farms, requested help in installing a drip irrigation system. Today, there are several irrigation projects across the Navajo Nation. Some are small scale drip systems while others are larger scale piped irrigation systems, like the one in Wheatfields. There, a 24-inch-diameter PVC pipe feeds water to several hundred acres in an attempt to renew farming and agribusiness in the area. The grand challenges for irrigation and water use the Navajo Nation are access to the water and local leadership and involvement in the irrigation projects themselves.

Thursday June 19th, 4:15 PM
Session 37: U.S. Water-Ag Footprints and Innovative Solutions

Soil and Water Management in the Northeast for Climate-Resilient Agriculture
Joshua Faulkner, U. Vermont Center for Sustainable Agriculture
Climate projections indicate the Northeast will experience increased precipitation and more frequent and intense storms and flooding, as well as drought periods of greater severity. These changing, and uncertain, moisture patterns and hydrologic occurrences will undoubtedly create conditions that are economically challenging for agriculture, but will also increase the likelihood of nutrient and soil loss and resulting water quality impairment. Agriculture will be, and is being, forced to adapt. Soil and water resource outreach, education, and applied research will be critical components of a successful agricultural climate adaptation approach. With improved management and innovative solutions, our agricultural landscapes can help capture excess moisture, reducing peak flows and nutrient and sediment loss, and increase partitioning of green water for use in dry periods.

U.S. Irrigated Agriculture: Trends and Challenges
Glenn D. Schaible, USDA

Increasing water scarcity due to growth in competing water demands and potential climate change present new challenges for agricultural water use and conservation. A sustainable future for U.S. irrigated agriculture depends in part on continued adoption of more efficient irrigation “production systems” and on how well on-farm water conservation contributes to water-management objectives at the watershed scale. This presentation will discuss: 1) the current status of U.S. irrigated agriculture (i.e., how much, where it occurs, what it produces, and its importance to U.S. agriculture); 2) traditional and emerging water demand/supply challenges; 3) the challenge for agricultural water conservation from onfarm and watershed perspectives; and 4) a broader ‘conservation’ perspective for a more sustainable sector.

Friday June 20th, 8:00 AM
Session 42: Green, Blue, Grey Management for Rangeland and Dairy

The Rime of the Modern Dairy-er: Water, water, here and there; how much can we drink?
Andrew Henderson, University of Texas Health Science Center

Dairy production in the US is a distributed production system that entails great geographic diversity; it also integrates a variety of related agricultural systems. Milk therefore represents an interesting case study of spatial variability, especially with respect to water, a critical component of sustainable agriculture.

Drawing on the results of a comprehensive life cycle assessment (LCA), this presentation will highlight water issues related to crop and dairy production in the US. We use a generalizable matrix approach to link milk producing locations and crop producing locations. This approach allows an analysis in which an inventory flow in milk producing area j can be decomposed into inventory flows in crop producing zones i.

Extracted water inventories for crop production can vary by a factor of 800, and competition with other water users adds two orders of magnitude of variability in water stress. Water quality, with respect to freshwater and marine eutrophication, is accounted for in terms of pollution impacts, rather than the conceptual grey water.

The Future of Irrigated Agriculture in the Central and Southern Great Plains
Dan Devlin, Kansas State University

The Ogallala Aquifer is a vast underground aquifer located in the Great Plains and underlies 450,660 square kilometers in parts of eight states and accounts for about 30% of the irrigated land in the United States. The regions overlying the Ogallala Aquifer are some of the most productive regions in the United States for growing alfalfa, cotton, corn, wheat, sorghum and soybeans. These crops provide cattle operations with feed for 40% of the feedlot cattle output in the United States. Farmers and ranchers in this region began intensive use of ground water for irrigation in the 1930s and 1940s. Estimated irrigated acreage in the area overlying the aquifer increased from 5.0 million ha in 1949 to 36.1 million ha by 2005. Irrigation use accounts for nearly 90% of the groundwater withdrawals from the Ogallala Aquifer. In many areas of the aquifer, especially the southern portion of the Texas High Plains and in northwestern Kansas, the saturated thickness has been reduced by as much as 40% of pre-development levels. It is conservatively estimated that current use is ten times the rate of natural recharge. Withdrawals greatly exceeding recharge rates have resulted in deeper water tables, reduced saturated thickness and lower well yields. In Kansas, by 2010, 30% of the groundwater stored in the aquifer had been used and it is estimated at current use rates, 69% of the groundwater resources will be depleted by 2050. Depletion is greatest in the central and southern portions of the aquifer with average water level changes in the Ogallala Aquifer from predevelopment to 2007 decreasing by state: Colorado -3.8 m feet; Kansas -6.8 m; New Mexico -4.7 m; Oklahoma -3.9 m; and Texas -11.1 m. Potential climate change impacts on the central and southern Great Plains managed ecosystems and society are profound. These changes may include increasing temperatures, larger daily rainfall amounts in extreme events, longer and more frequent heat waves, and related impacts on plant production, water supply, and human health. Annual precipitation is predicted to decline slightly while annual temperatures will likely increase by 1 to 3 C. This will have significant impacts on the regional economy and rural communities as crop and
livestock production will be adversely impacted. Higher temperatures will increase crop water demand and possibly increase irrigation demand from the Ogallala Aquifer. When one combines the projections of climate change with the certain reduction of irrigation availability, there is the potential for irreparable economic, environmental, and community impacts. As the nation’s and, in many ways, the world’s breadbasket, agricultural disruptions in this region have the potential to severely disrupt national and global food supply. Thus long-term strategies are needed to cope with the impacts of climate change and variability on water use and availability, crop production and the economic sustainability of this region. The region is currently studying the future of irrigated agriculture and how to sustain irrigation for as long as possible. This may include increased regulatory measures, new technology developments and voluntary reductions in water use.

Use of Graywater and Brackish Groundwater for Cotton Production
Zhuping Sheng, Texas A&M AgriLife Research

Use of alternative sources, such as graywater and brackish groundwater for irrigation becomes more attractive as less natural fresh water resources are available for agricultural production due to climate changes and competition of municipal, industrial and domestic uses. This paper presents findings from a field experiment that was designed to assess the potential and feasibility of using graywater and brackish groundwater for irrigation of cotton. In this study treatments include different irrigation supplies with either graywater or brackish groundwater and soil conditioning with mulch. During the experiment, water and soil samples were collected for chemical analysis. Heights of selected cotton plants were also monitored to evaluate impacts of irrigation water and soil conditioning on the cotton growth. The results show that cotton plants irrigated with graywater grow higher than those irrigated with brackish groundwater with no soil conditioning. However with soil conditioning cottons grew almost at the same rate regardless irrigation supply. Soil conditioning also increase the lint yield in comparison with those without soil conditioning. Even though soil salinity and sodicity were altered by heavy monsoon rainfalls, salts accumulated at the soil surfaces regardless of irrigation water source. Mulch also altered distribution of salinity and sodicity. Changes in soil salinity and sodicity were more impacted by significant interactions between irrigation supply and soil conditioning. With mulch conditioning, brackish groundwater could be used more efficiently. The results show promising potential for graywater irrigation for cotton production.
significant gap between expected water supply and demand in the Colorado River Basin in coming decades. The Basin Study quantified that one million acre-feet of water can be conserved from agriculture by the year 2060 to help fill the estimated gap—primarily through rotational fallowing, deficit irrigation and temporary or permanent water transfers.

Unique coalitions are developing in the Basin, intended to drive a proactive and collaborative approach towards real solutions. All too often, policy makers wait until crisis-mode to address an existing challenge; however, it is the goal of a new alliance—the Western Agriculture and Conservation Coalition (“Coalition”), comprised of regional and national conservation and agricultural organizations—to activate farmers to be proactive in their own future, a future filled with compounding pressures that will pose great challenges to agriculture in the arid West. This is a crucial moment in history to generate this kind of dynamic exchange.

There is a critical need to maximize opportunities for producers to undertake meaningful and applicable water-use efficiency and new infrastructure and conservation projects, especially where such projects prove most feasible and appropriate. It is simultaneously just as important to understand all consequences of how these actions will play out on individual producers, food production, rural economies, and habitat and ecosystem services.

Innovations in Water Banking to Reduce Regional Drought Losses
Bonnie Colby, University of Arizona

The water users and water managing agencies of the Colorado River Basin have long recognized the role of voluntary water transfer arrangements to assist the region in adapting to urban growth and extended drought. This presentation reviews new developments in water banking in several basin states, including initiatives to provide water for environmental needs. Guiding principles for water bank design and implementation are provided for new initiatives intended to improve regional resilience under the decreased supply reliability that accompanies climate change in many regions.