Sustaining Irrigated Agriculture with Declining Water Supplies

Tom Trout

Shown here is a side-by-side comparison of well irrigated corn *(left)* and water stressed corn *(right)*. Water stress caused by deficit irrigation results in shorter plants with less leaf area and curled leaves. If water is reapplied as these stressed plants tassel and form ears, about 50 percent of the yield can be salvaged.

Agriculture must substantially increase productivity over the next 40 years to feed the growing world population. Farmers are also being called on to contribute renewable resources for energy production. Production increases in the past have been partially met by expanding use of irrigation. Irrigated agriculture contributes about 40 percent of the U.S. and global crop value on about 15 percent of the cropped land. In the process, irrigated agriculture uses over 80 percent of the water consumed in many arid and semi-arid areas.

However, irrigation expansion has ceased in many areas of the western United States. There isn't any more water to divert from rivers, and water is being pumped from groundwater aquifers faster than the natural recharge rates. In fact, in many areas, including the southwest and west coast states and the southern High Plains, which stretch from Texas through western Kansas to eastern Colorado and western Nebraska, the irrigated area is declining.

Declining irrigation is also the result of increased competition for our finite freshwater supplies. Semi-arid irrigated areas like California, Arizona, Nevada, and the front range of Colorado and Utah are desirable places to live, and the new residents expect dependable water supplies. The residents also want to sustain and improve the green river valleys that meander through these regions and that provide recreational opportunities and critical habitat for plants and animals. Increased water use to sustain cities and natural environments will reduce water available to grow crops.

If we are to meet future food needs ...

... we must sustain irrigated agriculture and squeeze as much productivity as possible from every drop of water. This is the quest of a group of water management researchers in the High Plains of northern Texas, eastern Colorado, western Kansas, and Nebraska. This area requires irrigation for good crop yields. The snowmelt from the Rockies is not enough in most years, and the massive High Plains Aquifer (often referred to as the Ogallala Aquifer) is being depleted, especially in the south and central portions. Although each region of the High Plains has its own particular problems and oppor-

Sunflowers grow in mini-lysimeters at the ARS facility at Bushland, Texas. Several deficit irrigation treatments can be tested in a variety of soils in this lysimeter complex.

Center-pivot fields dot the high plains of Texas. Note that some of the fields have not been planted, possibly due to lack of adequate groundwater.

tunities, the researchers share a common goal—to sustain productive irrigated agriculture. They gather annually to share their research and results at the "Tearing Down the Walls (state borders)" meeting and the Central Plains Irrigation Conference (www.ksre.ksu.edu/irrigate/cpia.htm).

Northern Texas

Scientists at the USDA-ARS Conservation and Production Research Laboratory (CPRL) in the Texas High Plains near Amarillo have been working on maximizing irrigation water productivity for many years. The CPRL is near the southern end of the High Plains Aquifer, where water levels have been declining for many years and deep pumping depths make water expensive to extract. ASABE member Terry Howell and his colleagues at the CPRL Soil and Water Management Research Unit use large weighing lysimeters, essentially large square containers filled with soil and sitting in the ground on large scales, to precisely determine crop water requirements. Lysimeters are the standard for measuring water use on a daily and even hourly basis. With these large tools, the researchers can precisely measure water use and validate other, alternative ways to measure water use, such as instrumentation that measures the atmospheric energy balance at the surface. They recently invited researchers from across the United States to come to their fields and compare their own favorite water use measurement methods with each other and with the on-site lysimeters. The techniques included instrumentation placed just above the crop canopies and satellite remote sensing imagery. As researchers gain more knowledge and confidence in their ability to measure evapotranspiration, their ability to measure and describe the effects of climatic conditions, water stress, and deficit irrigation also increases.

One of the ways that crops respond to water stress is to close their stomates, which results in reduced water evaporation (evapotranspiration) and increased temperature of the crop canopy. ASABE member Steve Evett and his colleagues are building infrared thermometers that can measure canopy temperatures and indicate the level of water stress. Canopy temperature measurements can be used as a trigger to tell the grower, or the irrigation system directly, when irrigation should be started.

Recognizing the importance of sustaining the High Plains Aquifer as long as possible, the USDA-ARS began the Ogallala Initiative in 2003 with the mission to sustain rural economies through water management technologies. Through this program, the USDA-ARS funds water management projects in Texas and Kansas in a consortium with Kansas State University (KSU), Texas A&M University, Texas Tech University, and West Texas A&M University.

Western Kansas

ASABE member Freddie Lamm, an agricultural engineer at the KSU Colby Research Station and the ARS Central Great Plains Research Station, has been researching the use of subsurface drip irrigation in the High Plains for 23 years. He has shown that the systems can last that long if they are well maintained, and that they are a viable water-saving option for several of the crops grown in the region. With subsurface drip irrigation, the water is precisely placed in the soil root zone and uniformly distributed across the field to help maximize its productivity. Surface evaporation losses are minimized since the crop and soil surface are not wetted. Although the initial cost of drip systems is high, the resulting water conservation, high yields, and long life can combine to make drip systems a good economic choice.

One of the main irrigation limitations in many areas of the central High Plains is that the High Plains Aquifer is not very thick, and growers have already drawn down the water table, so the capacity of their wells has decreased. Center-pivot sprinkler systems that were installed with an adequate water supply 30 years ago may now pump only 50 percent as much water during the peak water-needs period. ASABE

Subsurface drip irrigation tubing is installed at Kansas State University, Colby, Kan.

"Most of the ag and bio engineers named in this article are near retirement, and I wonder how we will replace them, yet ...

member Norm Klocke, an agricultural engineer at the KSU Research and Extension Center in Garden City, Kansas, and Allen Schlegel, an agronomist at the KSU Southwest Research and Extension Center in Tribune, Kansas, along with Joel Schneekloth, a regional water resource specialist at Colorado State University (CSU), are developing management strategies that will allow growers to maintain productivity with the reduced pumping capacity. Practices include planting two different crops that have varying water needs and schedules under the same center-pivot system. For example, an early-season crop like wheat reaches maturity and has reduced water needs by the time a later-season crop like sunflowers reaches full demand. Through good crop rotations and tillage practices that maximize conservation of both rain and irrigation water, growers can get additional productive years from their wells.

One of the constraints to adoption of deficit irrigation practices is that most farmers depend on federal crop insurance to insure their crops against unplanned catastrophes such as hail or extreme drought. However, the USDA Risk Management Agency (RMA), which manages the Federal Crop Insurance Program, does not know how to establish the potential yield of a crop that is deficit irrigated, so the agency currently insures deficit-irrigated crops at the same rates as lower-yielding dryland crops. ASABE members Norm Klocke and Derrel Martin, ag engineers in Kansas and Nebraska, have been working with the RMA to establish the likely crop yields under different planned deficit-irrigation practices. When farmers know that they can get their crop insured for its intended yield, they will be more willing to try deficit irrigation.

Eastern Colorado

Growing populations, energy development, and overuse of water are resulting in declining water supplies for irrigation in eastern Colorado. Cities have been buying irrigated land to acquire the rights to use the water—a tactic called "buy and dry." Senior water rights holders in the "first in time, first in right" prior appropriation system have been requesting that the upstream well pumpers stop pumping. At the same time, oil and gas exploration companies are leasing any available water for future use in hydraulic fracturing.

CSU and the USDA-ARS are partnering with water districts and private companies to devise ways to sustain the rural agricultural economy in the region. CSU soil scientist Neil Hansen and his colleagues at KSU and the Central Great Plains Research Station at Akron, Colo., have been developing conservation practices for dryland (non-irrigated) agriculture and are applying these practices to limited-irrigation production systems. Reduced tillage and maintenance of surface residues helps collect rainfall, snowfall, and sprinkler water and reduces evaporation losses. Hansen and his colleagues are developing cropping rotations appropriate for ranges of water supplies from dryland to full irrigation. They have shown that an alfalfa grower with inadequate water can use the limited supply in the spring and fall and let the crop go dormant in the heat of summer and still maintain a viable crop.

The irrigation control center for deficit irrigation trials at the ARS Limited Irrigation Research Farm near Greeley, Colorado. Irrigations are controlled through a data logger and measured with flowmeters.

The USDA-ARS Water Management Research Unit (WMRU) in Fort Collins, Colo., is conducting a detailed study of plant responses to deficit irrigation and how to maximize the "crop per drop," or more specifically, the dollars per drop. The WMRU researchers are developing water production functions based on crop evapotranspiration to quantify the value of water with different amounts of irrigation. Colorado water law accounts for water in terms of water consumed by the crop rather than irrigation water applied, since water that is not consumed is generally available for others to

ARS engineer Jordan Varble measures soil water content down to 2 m depth in wheat with a neutron moisture meter.

I have enthusiastic hope that students and young professionals reading this might be inspired to carry on this important work!" TT

use downstream. In Colorado, which has interstate compacts with all its neighboring states on both sides of the Rockies, leaving some water for downstream users is critical. ASABE member Walter Bausch is using remote sensing from both the ground and the air to estimate crop stress and determine how much water is actually used by a stressed crop. He is finding that canopy size and temperature are good parameters to help estimate water use.

One of Bausch's findings is that many crops are very efficient in using the water they receive, so getting more crop per drop with deficit irrigation will require better understanding of how crops respond to water stress. Plant physiologists Dale Shaner and Louise Comas are studying water-stressed plants in detail to see if there are particular irrigation schedules that will help a plant maintain productivity with less water use, and if there are plant characteristics that can be measured to indicate degrees of stress.

ARS engineer Garrett Banks measures soil water content in wheat with a portable TDR device.

Realizing that research from a given field will not apply to all situations, the WMRU is working closely with the USDA-ARS Agricultural Systems Research Unit in Fort Collins to collect field measurements that will validate and improve crop models, such as the Root Zone Water Quality Model, so that these models can predict crop yields under water stress for a wide range of conditions. This is especially important as we face future climate change.

The WMRU is also working closely with a Cooperative Research and Development (CRADA) partner, the Regenesis Management Group, on the Sustainable Water and Innovative Irrigation Management system. Regenesis will incorporate the water productivity research results into decision support systems that will help farmers value their water as a commodity. Water can be used both to produce high value on the farm and for potential income from a city in need of water in times of shortage. The goal is to keep farmers in control of their water supplies. A critical part of the effort is to document water savings to the satisfaction of downstream water users, who are always wary of changes upstream that might affect their water supply. CSU agricultural economist James Prichett is furthering these efforts by surveying farmers to learn how much they feel their water is worth and what types of lease arrangements they might be willing to agree to. All these efforts are designed to sustain productive and economic irrigated agriculture while meeting the water needs of others.

Western Nebraska

With recent declines in irrigated area in California and Texas, Nebraska is now the state with the greatest irrigated area. Sitting at the north end of the High Plains Aquifer and on the Platte River drainage, Nebraska, the home of many center-pivot manufacturers, is relatively well supplied with water. However, in the western part of the state, water shortages are critical. In Nebraska, regional Natural Resources Districts monitor and regulate irrigation water use. Declining water levels in the High Plains Aquifer have led to restrictions on pumping, but recognizing that these effects are long term, the Natural Resources Districts often restrict the amount a farmer can pump over a multi-year period. Thus, farmers must decide the value of the water this year for a particular crop mix and precipitation pattern compared to next year—a very complex decision. Derrel Martin, working at the University of Nebraska, and his colleagues have developed the Water Optimizer to help farmers weigh the many options involved in water management decisions. Farmers can input information on their water supply, preferred crops, and production costs, and the Optimizer will help them allocate their limited water supply to gain the best overall returns.

Investigating the options is the future

Although the challenges facing irrigated agriculture in the High Plains and in the rest of the western United States are daunting—farmers must produce more with less—failure is not an option if we are to meet the food and fiber needs of the next 40 years. Through many researchers from many institutions working together, our understanding of the options is increasing. Technological breakthroughs, such as new crop varieties that resist water stress, may play a critical role in meeting food needs with limited water resources, but past experience shows that good water and crop management will always be an important part of the solution.

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