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Water Science and Research Issues Associated with the Future of Water for Food

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Richard Allen's research focuses on evapotranspiration, irrigation water requirements and hydrologic systems. Allen was the lead author of the United Nations Food and Agriculture Organization publication "Crop Evapotranspiration," which serves as an international practice standard. He also was co-editor of the American Society of Civil Engineers Practice Manual 70, "Evapotranspiration and Irrigation Water Requirements." Allen has been a consultant to the United Nations, the World Meteorological Organization, the United States Agency for International Development and the governments of Portugal, Spain and Australia, with missions to India, Pakistan, Jordan, Yemen, Morocco, Egypt, South Africa and Turkey. He is a member of the NASA/U.S. Geological Survey Landsat Science Team.

Rick Allen

Richard Allen introduced his talk with this primary question: *How can we manage the spatial and temporal distribution and redistribution of water to enhance food production?* Better tools are the answer, Allen said.

Microsupplies versus macrosupplies

Allen made a distinction between developing countries and developed countries. In developing countries, research should concentrate primarily on the microsupply systems, such as micro drip and mini sprinklers and the widely successful treadle pump. The treadle pump is an inexpensive way to bring water supplies to farmers who can only afford a $20 to $100 investment. The pump only works with a shallow groundwater system, but this rarely is a problem, especially in areas (such as parts of India) where the pumps address waterlogging problems.

The treadle pump was developed by International Development Enterprises and has been supported by the Food and Agriculture Organization, World Bank and the Gates Foundation. These organizations are focusing on getting microsupply systems to farmers in the villages by creating local business systems to produce the equipment, avoiding the significant bureaucratic obstacles found in many countries. The greatest impact of these systems is that they move farmers from subsistence farming to reliably growing a high-value cash crop, putting money in their hands for educating their children, Allen said.

Macrosupplies, such as large reservoirs, must be considered in both developed and developing countries. Allen cited George Hargraves, a Utah State University researcher, who 10 years ago pointed out that while reservoirs have some large environmental problems, they also provide a major benefit by concentrating farming in river valleys. Concentrating the food production in a country like Brazil might actually reduce slash-and-burn agriculture, which is highly erosive and has other adverse ecological impacts. Allen concurred, stating that the environmental impacts of reservoirs must be weighed

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against the impacts of existing production systems. "You've got to kind of pick your poison in a way," Allen said. "If we're going to produce the food, if we're going to enable countries to be self-sufficient with food, sometimes the less toxic poison might be some surface reservoirs and more concentration of irrigation."

Allen added that groundwater aquifers must be better utilized. Unlike surface water reservoirs, aquifers have significantly less evaporation loss and don't inundate land. Supplementing supplies with water from groundwater reservoirs could be a major tool to help meet the challenges of climate change, including the kind of "gorilla" droughts described by James Goeke.

Improving food productivity per unit of water consumed

Allen questioned whether gains in biomass per kilogram of water consumed are hitting a natural plateau, especially when factoring in transpiration and evaporation. He cited a recent publication by Zwart and Bastiaanssen stating that over the last 25 years, the amount of biomass produced per unit of water consumed has not increased. Allen emphasized this is the amount of water consumed by plant transpiration, not the amount of water pumped to irrigate the plant. He firmly believes that genetic combinations exist that will make crops more productive, but production increases will be more difficult to achieve than in the 1970s and 1980s. Improving the harvest index will increase yields, Allen said, but he cautioned that some ecologists believe that big increases in the harvest index have passed. His conclusion: Improving management of water to increase food production will be one of the big issues in the next decade.

Nebraska Sand Hills lake

Reducing non-beneficial consumptive use of water

One efficient way to increase food production per unit of water consumed in developing countries is to increase transpiration and decrease evaporation losses, Allen said. He described a conversation with Eugene Glock, a Nebraska farmer, about no-till and minimum tillage practices actually reducing non-beneficial evaporation of water during both the off season and the growing season, making more water available for crop use.

"Can we just genetically and mechanically try to get full ground cover more quickly with our crops so that we get more transpiration and less evaporation?" Allen asked. He referred to a study in Idaho by Jim Wright of the U.S. Department of Agriculture, who measured the ratio of evaporation to precipitation during winter and found it to be quite high. Allen suggested that if this process can be inverted so that winter precipitation gets stored in the root zone instead of evaporating, this water could be used for transpiration in the growing season. It might be possible to harvest 50 to 100 millimeters of water per year and convert it to transpiration and increased food production. "That might be some of the more easy water to find," Allen said.

Manage water consumption, not irrigation efficiency

Allen also argued for better accounting of water, particularly in managing water consumption. He cited a paper by Frank Ward in the *Proceedings of the National Academy of Sciences* describing an effort to get more water into the Rio Grande River by subsidizing farmers to convert to more efficient irrigation systems, leaving more water in the river for downstream uses. But rather than conserving water, the efficient systems distributed water more evenly across the field, increasing transpiration and crop production. "Now, that's a good thing for crop production, and the crop went up, but the bottom line was that there's less water in the Rio Grande River downstream, which was part of the reason for this whole subsidy," Allen said.

It is important to define clear objectives for water management solutions, Allen said. If the objective is to simply increase crop productivity or relieve waterlogging problems, increasing water use efficiency is a good idea. But if the objective is to conserve water so it's available for new uses, increasing efficiency may be detrimental. In Allen's view, USDA Natural Resource Conservation Service programs that provide funds to farmers to use higher efficiency irrigation systems actually increase, not decrease, water consumption. He suggests these programs should be renamed as evapotranspiration sustaining programs.

Adopting a holistic basin approach

Allen also emphasized the importance of examining the big picture and adopting a more holistic, basin-based approach to water accounting. It is important to appreciate the close connection between surface water and groundwater and recognize that groundwater lies underneath 99 percent of the earth's terrain. In many cases, water "lost" in the field to deep percolation through the soil zone is not really lost because it recharges the groundwater. This groundwater then becomes available for another use. Water accounting also should recognize the reuse of water. Allen quoted Lyman Willerson of Utah State University, who said if people want to know how much they can increase a basin's total water consumption, go to where that water reaches the ocean. The water flowing into the ocean is the only excess water in the system.

Treadle pump

Allen believes the need for a more holistic approach to water accounting is becoming more apparent, citing the Web sites http://wateraccounting.com and http://winrockwater.org, which includes a forum to discuss water accounting, increasing water productivity and the need to adopt a river basin perspective.

The Idaho Legislature also is taking a more holistic approach to managing the Upper Snake River Basin aquifer to address conflicts over water use in the basin. The Snake River Plain aquifer holds as much water as Lake Erie and is a dynamic system with a

close coupling between surface water and groundwater. Most of the water in the aquifer is from snow melt in the Teton Mountains and Yellowstone National Park area that is diverted from the Snake River into leaky canals that provide water to recharge the aquifer. In the first half of the 20th century, water levels in the aquifer increased because of inefficient irrigation systems. The higher water levels in the aquifer then increased discharge into the river.

> *"Improving management of water to increase food production will be one of the big issues in the next decade."*

The spring discharge in the Thousand Springs, Idaho, area, which produces 80 percent of the trout found in American restaurants, relies on this spring discharge, which varies annually based largely on the amount of recharge from surface water irrigation. When irrigation from groundwater wells began around 1950, those irrigators depended on seepage and deep percolation from the canals for their groundwater supply. But as the number of wells increased, water in the aquifer and the Snake River decreased. According to Allen, because groundwater pumping is decreasing the water in the springs that supply the surface water users and aquaculture, there are several lawsuits between surface water users and groundwater users. One objective of the Legislature's plan is to maintain recharge to the aquifer by allowing seepage from canals to continue where it will benefit a groundwater or spring user.

Work with fractions, not efficiencies

To make water accounting more transparent and better understand how to make more water available for new uses, Allen advocates working with fractions instead of efficiencies. For example, describing an irrigation system as 40 percent efficient implies that 60 percent of the water diverted is wasted. In contrast, if considering the ratio of evapotranspiration to diversions (the amount of water consumed by evapotranspiration divided by the amount of water diverted), it's apparent that 40 percent of the water diverted was consumed and lost to the system, while 60 percent of the water was returned to the system for reuse and no water was wasted.

Quantifying water supplies and uses

Allen also believes scientists must better quantify the available water supply and the amount of water consumption through improved groundwater surveys, water balance studies and models, and quantifying evapotranspiration by various water uses. Allen described two processes that use Landsat satellite images to quantify evapotranspiration. The Surface Energy Balance Algorithm for Land (SEBAL), developed about 15 years ago by Bastiaanssen and Holland, is now used throughout the world. The Mapping Evapotranspiration at High Resolution with Internalized Calibration (METRIC) model, developed by Allen in collaboration with University of Nebraska–Lincoln researchers Ayse Irmak, Gary Hergert and Gary Stone, is a similar process used in the U.S.

SEBAL and METRIC use Landsat satellite images to take a snapshot of how much evapotranspiration occurs in an area at a given time. These images can be overlaid on maps of water rights to provide valuable information for lawsuits, mitigation efforts and water transfers. Allen has used aggregated METRIC evapotranspiration data to determine the performance ratio for a canal in the southwest part of the Snake River Plain aquifer. The performance ratio showed that the canal company was evaporating 40 to 50 percent of the water it diverted. That means that 50 to 60 percent of diversions return to the river as surface water returns or recharge the groundwater aquifer. Allen said he couldn't resist bragging about the Idaho Department of Water Resources, which

is one of the 16 finalists out of a thousand applications for the Harvard University's American Government Awards this year for its use of METRIC for water rights and groundwater management programs.

Allen also described a study by Bastiaanssen using SEBAL to make a map that shows in millimeters the annual water consumption of rice in an area of Iran. Using estimates of the biomass of the harvestable rice, Bastiaanssen was able to develop a water productivity curve map. This information enables managers to determine where they should focus their efforts to decrease the non-beneficial consumption of water and make more water available for new uses.

Allen concluded this type of water measurement will be very important in adapting to the impacts of climate change on water supplies, which will include higher evapotranspiration, longer growing seasons, less snow and earlier snow melt, which affects reservoir supplies for irrigation.