Applying Tree-Ring Data to Water Resource Planning

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Trees that reflect variations in moisture in their ring-width patterns can be used to reconstruct records of streamflow for past centuries, extending stream gauge records and providing a long-term context for evaluating recent droughts and low-frequency hydroclimatic variability. When extended records of streamflow are incorporated into models, the performance of water supply systems can be tested using a broader range of values and a richer sequence of flows than are contained in gauge records.

One motivation for using tree-ring records has been the recent widespread drought and questions regarding how persistent and severe droughts were in centuries before gauged flow data were available. By using tree-ring data, we can expand our capability to assess the true potential and risks of future severe drought in the Southwest.

A principal challenge to more widepsread use of tree-ring data for water resources planning has been integrating the data into a typical modeling environment. Tree-ring data are in the form of annual time steps from specific locations, whereas models require daily or monthly time steps from multiple locations.

Several technical training workshops have been held over the past year in Arizona and Colorado to teach water managers and consultants about the methods used to reconstruct hydrology from tree rings, including field and laboratory methods, data processing, statistical calibration techniques, and application approaches. The workshops were designed to provide participants a better basis of understanding from which they might apply tree-ring data in their own water resources planning. Most recently, a number of water resource professionals convened at a May meeting at the University of Colorado in Boulder to share their experiences.

Who's Using Tree Rings?

Denver Water used tree-ring-derived flow reconstructions of two key gauges to help model the yield of its system under a broader range of conditions than those seen in the utility's 45-year model period (1947-1991). The results showed that a four-year drought such as one that occurred in the mid-1800s would reduce water supplies to the level of the system's strategic reserves, even with progressive restrictions on water use.

The City of Boulder and its consultants extended a 95-year stream-gauge record using a 300-year record of tree-ring hydrology. These data were used to develop a drought plan based on the climatic and hydrological effects of past droughts on the city's water supply. The work is being expanded to incorporate tree-ring-based temperature and precipitation reconstructions to examine what might happen if the droughts of the past occurred again under warmer and drier conditions.

The U.S. Bureau of Reclamation used a 500-year tree-ring reconstruction of Colorado River flow at Lees Ferry for modeling done in conjunction with the development of shortage criteria and coordinated operations for Lake Powell and Lake Mead. Reclamation's approach extracted information on the state of the system in a given year—whether the flows were above or below average—from the tree-ring record, and then assigned a specific flow magnitude for that year based on the observed (stream gauge) flow record to generate a set of 500 60-year flow simulations. Not surprisingly, using information from the longer tree-ring record generated a greater probability of system shortages than when models were run using only the observed record.

Salt River Project and the University of Arizona used tree-ring data to investigate how often droughts occur simultaneously in the Upper Colorado River Basin and the Salt-Verde-Tonto river basins. The results showed that synchronous low-flow years are common, thus surpluses in one basin would not be a reliable buffer for shortages in the other. Furthermore, low-flow years tend to cluster in time, heightening the stress on water resources.

Additional water providers present at the Boulder meeting who are interested in incorporating tree-ring data into future planning include Western Area Power Administration, Colorado Springs Utilities, and the Colorado cities of Aurora, Colorado Springs, Pueblo, and Thornton.

More information can be found on the University of Colorado Western Water Assessment web page, Tree-Ring Reconstructions of Streamflow for Water Management in the West (wwa.colorado.edu/resources/paleo/). Contact Connie Woodhouse at conniew1@email.arizona.edu.

Urban-Scale Climate Change Effects on Water Use

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Global climate change is not the only climate-related issue with far-reaching regional consequences. Urban-scale climate change can complicate global climate change scenarios and affect local water use. Urban effects are especially significant in the Southwest where most of the population lives in large, rapidly growing urban areas.

Global climate affects water use in metropolitan regions, but these impacts may be compounded by local-scale climatic processes. One example is the well-known heat island effect, the tendency for urban surfaces to absorb heat during the day and release it at night, leading to higher nighttime temperatures in the urban core than in the surrounding rural countryside.

Recent research at the Decision Center for a Desert City at Arizona State University's Global Institute for Sustainability has focused on the interrelationships among water, climate, and growth in metropolitan Phoenix.

Long-Term Trends

Balling and Gober (in press) related temperature, precipitation, and the Palmer Hydrological Drought Index (PHDI) to annual variations in per capita water use in Phoenix. As shown in the chart below, from 1980 to 2004, water use declined 15 percent overall to 835 liters per capita per day (pcpd), a trend likely associated with the city's conservation plan. The authors found an upward trend in temperature of 0.03ºC per year that reflects both regional warming and urban heat island effects associated with urbanized portions of the city. Precipitation decreased by 3.81 millimeters (mm) per year. The PHDI shows a slight trend toward drought during the period.

Short-Term Responses

Next, the residual values of the regression line of per capita water use over time were studied to reveal short-term, city-wide responses to climate variables. Residual values showed that for every 1ºC increase (or decrease) in temperature over the short term, residential water use increases (or decreases) by 60.76 liters pcpd. Yet a reduction of 10 mm per year in precipitation increases water use by only 4 liters pcpd. These results suggest that residential water use is relatively insensitive to climate variation. The finding was somewhat surprising considering two-thirds of all water use is for outdoor purposes, but reinforces the fact that water use is inherently a human-dominated activity, and residential water often is delivered outdoors by automated irrigation systems that are reset only seasonally if at all.

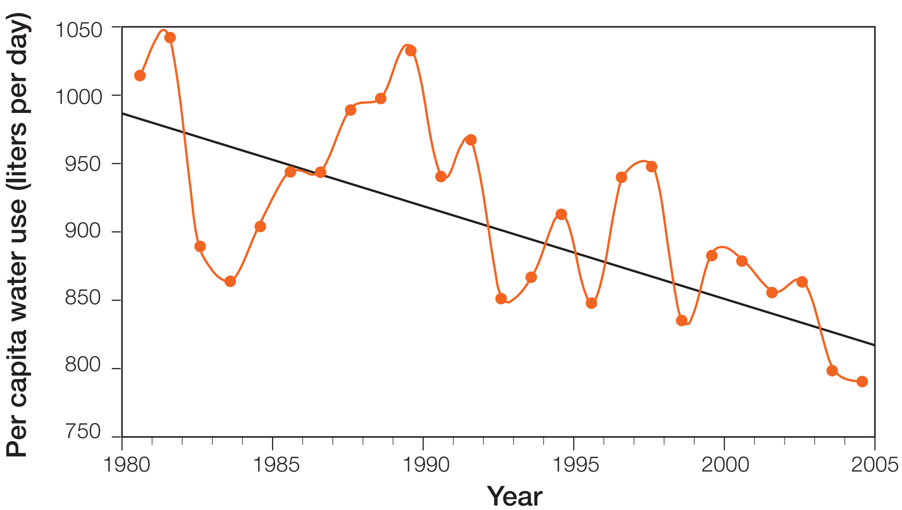
Variability Between Neighborhoods

Guhathakurta and Gober (in press) explored the effects of urban temperature differences across census tracts in Phoenix on residential water use. The authors found that census tracts that are 1ºC warmer use 1,976 liters (522 gallons) of additional water per month for a typical single-family home (about 49 liters pcpd). The results also suggest that urban heat island-related rises in water demand should be considered by planners as they evaluate environmental consequences of growth strategies such as infill and more compact forms of urban development. More compact cities may reduce the demand for water for outdoor purposes, but increase the demand due to urban heat island effects.

Wentz and Gober (2007) researched the determinants of variability of water use for single-family residences in Phoenix. The addition of new household members and pools, as well as differing lot sizes and landscaping methods, had varying effects on water use in different parts of the city. After accounting for the main indicators of indoor and outdoor water use, the researchers identified a "neighborhood effect"—households in one tract used a similar amount of water as those in neighboring tracts.

New Directions for Planners

Additional atmospheric modeling studies will determine the effects of evapotranspiration (ET), evaporation, soil moisture, and temperature on water use at the local scale for a variety of variables. Initial analyses suggest that over 30 percent of the combined ET and evaporation can occur post-sundown when the heat island is at



City of Phoenix per capita water use (liters per day) shows a trend of 15 percent decline from 1980 to 2004.

a maximum. A deeper understanding of climate, water, and urban growth relationships is key to understanding how best to plan for more sustainable urban growth in the Southwest.

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