Maintaining urban landscape health and services on reduced irrigation: a multi-site study in best management practices

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Abstract

Urban landscapes in summer-dry climates face challenges to survival in the face of increasing water-use restrictions. Stringent regulations designed to reduce water use and waste have been established in much of the western/southwestern US due to ever-increasing populations and predictably cyclical droughts. To address this issue in California, the state Department of Water Resources collaborated with University of California researchers and a consulting landscape management contractor to implement conservation measures and best management practices (BMPs) in established urban landscapes across the state to see if these steps were sufficient to maintain acceptable plant health at a targeted water reduction level. Thirty sites in six distinct climate regions, that included parks, universities, private grounds, business parks, and golf courses were initially evaluated for irrigation system status, plant mix, and maintenance practices. BMPs were implemented: irrigation system repairs with improvements and optimization based on initial audit; irrigation scheduling based on climate, microclimate, planting density and species mix; application of organic mulch; and proper fertilization. Site personnel were given guidelines to maintain the BMPs over the period of two years. During this time, periodic observations were made on plant health, and follow-up audits were conducted on irrigation systems. Twenty-one of the 30 sites significantly reduced water use and waste the second year of the project compared to the first year by implementing the BMPs. In the hotter regions, some of the turfgrass areas saw a decline in health at the reduced water level, but shrubs maintained good health and performance at all sites. Failures to meet the reduction goals were generally due to lapses in following the BMPs or system failures that went unnoticed and therefore uncorrected by on-site maintenance personnel. Some sites realized a 50% or more reduction in water use without compromising plant health and accompanying ecosystem services.

Keywords: water conservation, irrigation scheduling, evapotranspiration adjustment factor, turfgrass maintenance

INTRODUCTION

In response to water shortages, California passed a comprehensive Water Conservation Act requiring reductions in agricultural and urban water use (State of California, 2009). In 2010, additional restrictions were put in place for urban landscape water conservation, without regard for the potentially negative consequences for landscape and urban forest health and accompanying ecosystem services such as urban temperature reduction, wind speed reduction, stormwater interception and filtering, and improved air quality (Bolund and Hunhammar, 1999; Elmqvist et al., 2015; Livesley et al., 2016).

Experienced landscape managers understand that optimizing irrigation system

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efficiency can result in significant water savings. Optimization may include shifting from spray to drip irrigation in non-turf areas, changing static spray heads in turf areas to rotary heads, and improving the distribution uniformity of systems in turf areas through head-to-head coverage, matched precipitation rates, pressure regulation, and proper vertical alignment of heads (Hartin et al., 2014). Other practices known to enhance water use efficiency include moderate or no supplemental fertilization to prevent excessive foliar growth, application of organic mulch to soil surface in shrub beds, higher mowing heights for turf, and irrigation scheduling to match weather and plant water needs based on type and density (Harivandi et al., 2009). The California Department of Water Resources (DWR) recognized the need to evaluate best management practices (BMPs) as a method for reaching targeted water reductions on established landscapes to assess the feasibility of the stricter requirements.

At the time of the study, the California Model Water Efficient Landscape Ordinance (MWELO) established a water budget based on local reference evapotranspiration (ET_0), an evapotranspiration adjustment factor (ETAF), and the landscaped area (LA in ft^2). The maximum applied water allowance (MAWA) was then calculated thus: $(ET_0)(ETAF)(LA)(CF)$, where CF is a conversion factor of 0.62 to yield gallons of water allowed (State of California, 2010). Local ET_0 values are available in an online reporting system using hourly data from a wide network of weather stations across the state (California Irrigation Management Information System or CIMIS), and are estimated from calculations based on the water use of the reference plant: well-watered, actively growing, consistently clipped tall fescue turfgrass in which the stations are located. ETAF adjusts the ET_0 based on the plant factor (PF) and irrigation efficiency (IE) by the equation ETAF = PF/IE. Plant factors represent the water use category of plants as percentages of ET_0 as described in Water Use Classification of Landscape Species (WUCOLS), where HIGH water use is described as 70-100% of ET_0, MODERATE is 40-60% of ET_0, and LOW is 10-30% of ET_0 (University of California, 2014). To reach the target ETAF, landscapes need an average PF of 0.5 and an average IE of 0.71. Irrigation efficiency is the ratio of the amount of water effectively used by the landscape to the amount of water applied. This project set this value at 71% (0.71), an increase in irrigation efficiency from previous versions of the MWELO (62.5%). This expectation of reaching this value was based on industry improvements in irrigation systems since the original ordinance. The purpose of the study was to determine if an ETAF of 0.7 was attainable through landscape BMPs without compromising overall landscape health.

METHODS

Study sites were chosen within each of six geographic regions of the state defined by DWR based on climate. These sites comprised a variety of species mixes, landscape irrigation technologies and practices, microclimates, and densities in several climatic zones: four sites from the Central Coast; five from the Desert, the Inland Empire (southern interior), the Los Angeles Basin, and the South Coast; and six sites in the Central Valley. Each region's sites were representative of its climate. Sites were initially evaluated for plant mix to determine the average PF. At least two sites within each region had a plant mix with an average PF of 0.5, and at least one site had a large area of turf. Irrigation systems were audited to evaluate initial distribution uniformity (DU), and corrected to 0.7.

Sites began recording water usage during 2014 using either water meters (21 sites) or water sensors (9 sites). Water usage was then recorded monthly for a period of 24 months, ending either in 2015 or 2016, depending on when meters or sensors were fully operational in 2014. Each site was given a monthly water budget (MAWA), which used historical ET_0 data from a local CIMIS weather station, an ETAF of 0.7, and the landscaped area in square feet.

$$\text{MAWA} = (ET_0)(\text{ETAF})(\text{LA in ft}^2)(0.62)$$

Each site was inspected quarterly during the length of the study. At each event, an irrigation maintenance inspection was conducted to make sure all systems were operating properly. This consisted of measuring the system static and dynamic pressures, water pressure at the sprinkler, a base water flow from the valve in gallons min^{-1}, correct valve operation, rotation times of rotary sprinklers, and the soil moisture depth measured with a probe. Irrigation audits (catch-can tests) were performed on all turfgrass sites to measure sprinkler distribution uniformity and precipitation rate. Issues encountered at the sites were fixed, including sprinkler repair, arc adjustments, clearing plugged nozzles or emitters, leveling uneven or tilted sprinkler bodies, replacing mismatched nozzles with matching ones, and trimming or removing plant material from around sprinkler bodies whose sprays were deflected by foliage.

Plant observations were made quarterly to assess plant health and attractiveness. Non-irrigation factors, including both biotic and abiotic disorders, were documented, as well as the overall impact of the irrigation budget on the landscape. Photographs were taken of the plants and landscape during each visit, and the plant canopy coverage was estimated. Water usage was recorded monthly at all sites and compared to the 0.7 ETAF water budget.

At the end of 2014, managers of sites that exceeded the water budget were requested to adjust their schedules to reach the target. In 2015, in response to an ongoing drought, statewide emergency restrictions were enacted. Some of these restrictions included reducing the number of weekly watering days allowed, causing some sites to reduce their total applied water even further.

RESULTS

Twenty-one of the 30 sites met the 0.7 ETAF goal by the end of the study (Figure 1). The fourteen turfgrass sites increased distribution uniformity by an average of 13% by switching from spray to rotating nozzles, performing regular sprinkler maintenance during audits, replacing rotary sprinklers that were turning slower than the manufacturer specifications, replacing worn-out rotating nozzles with new nozzles, and matching nozzles to the pressure, spacing, and the other nozzles in the system.

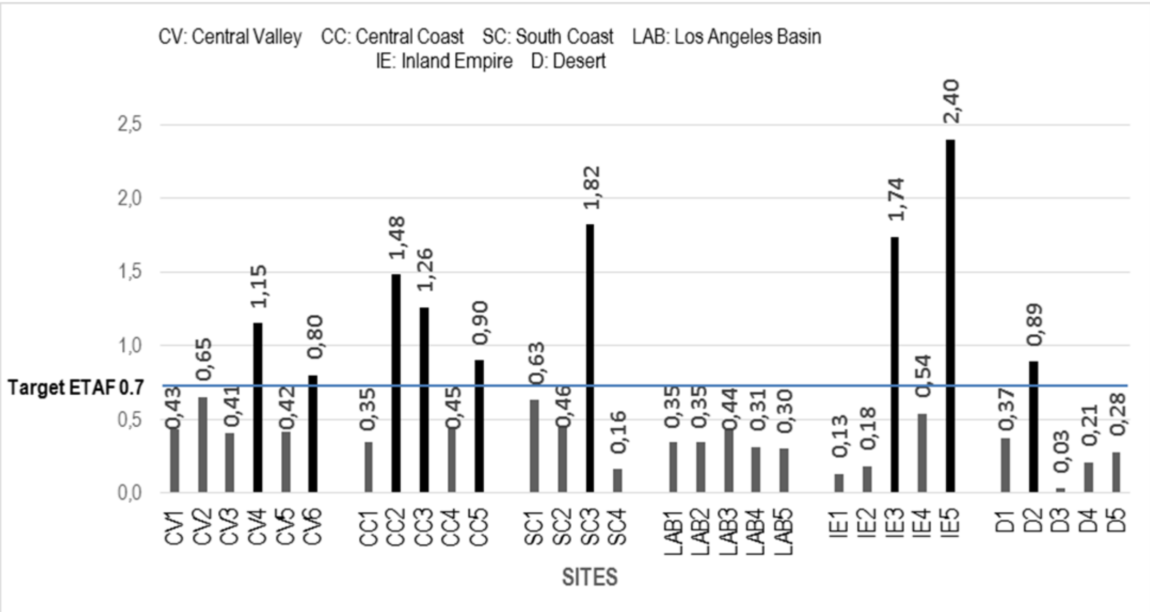

Figure 1. Actual average annual evapotranspiration adjustment factor (ETAF) at 30 landscape sites in 6 regions of California in 2015/2016, year 2 of the study.

All turfgrass sites decreased their individual water consumption. The combined usage of all turf sites was 11,504,366 liters in 2014, and 9,326,316 liters in 2015/2016, for a water savings of 2,181,050 liters, or a 19% reduction in water usage.

In 2014, turfgrass sites had a combined actual ETAF of 1.28, which lowered to 0.89

during 2015/2016. The total area of grass at these 14 sites was 14,226 m^2. An average of 815 L m^{-2} was used in 2014. In 2015, the amount of water was reduced to 652 L m^{-2}. Eight of the 14 turf sites had grass conditions just meeting acceptable standards due to the state-required water reductions. The remaining six sites maintained an acceptable standard of color and coverage.

On average, turfgrass did not perform adequately at the 0.7 ETAF goal. Even so, a significant reduction in water usage was realized between 2014 and 2015/2016. Some of this reduction was achieved because of mandatory state water restrictions in 2015/2016, but significant contribution was due to irrigation system maintenance during the two years of quarterly inspections which improved sprinkler distribution uniformity considerably during this period.

The 24 sites with landscape beds containing shrubs used considerably less water than the turfgrass. In 2014, water consumption was 4,777,190 L or 530 L m^{-2}, compared to 815 L m^{-2} for grass. During 2015, the total water usage for shrubs increased to 570 L m^{-2}, which was still below the budgeted ETAF of 0.7. Irrigation in 2014 was at an actual average ETAF of 0.58, and increased to 0.61 in 2015/2016. Fourteen of the 24 shrub sites reduced water consumption in 2015/2016. The 386,112-liter increase in 2015/2016 was due to three sites that had valves stuck in the open position for extended periods of time. Also, one site had three different managers during the study period, with little or no continuity between supervisors to ensure the continuation of efficient water application practices.

Nine of the shrub sites had drip irrigation, and in 2014 applied water at an average of 0.35 ETAF. In 2015/2016, water applications were reduced to an average 0.29 ETAF. All shrub sites performed adequately with no adverse effects to plant health during the course of the study, even at the lowest ETAFs, partly because plant selections at these sites were appropriate to the climate and the irrigation level.

CONCLUSIONS

Landscapes comprised of moderate to low water-use shrubs and/or turf can maintain good health and appearance at an evapotranspiration adjustment factor of 0.7 when best management practices are employed and maintained. Regular irrigation audits and maintenance lead to significant water savings. With current irrigation technologies, it is possible to reach 71% irrigation efficiency with overhead delivery systems, but cool-season turfgrass, which is the most widely used turfgrass type in California, will not perform consistently well at 50% of ET_0. For this reason, reaching the current conservation goals will require reducing the percentage of cool-season turf in the total landscaped area of a site, and replacing it with plants that require less water. An additional tactic is to replace the cool-season grasses with warm-season species, which can be irrigated at the lower rate of 50% of ET_0 with little or no adverse effects on health or appearance (Harivandi et al., 2009). Since beds with moderate to low water-use shrubs, groundcovers and trees can more easily be irrigated with drip systems, which can reach irrigation efficiency levels above 80%, the conservation potential for these plantings is even greater.

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